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MODERN FISHING GEAR OF THE WORLD 2:

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For convenience of presentation this book is divided into three parts relating to different aspects of the industry.

At the end of Parts I and II there are advertisement sections. These are included because it is appreciated that practical commercial information should be readily available about fishing gear and equipment procurable from various sources for the betterment of fishing practices.

An index of these advertisers' announcements appears in each section.

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PREFACE

THE book Modern Fishing Gear of the World, resulting from the first FAO Fishing Gear Congress held in Hamburg in 1957, sold out and had to be reprinted. This confirmed the belief that there existed a great need for a comprehensive work on fishing gear and fishing technology. The book was widely hailed and has undoubtedly stimulated gear development and the application of modern methods in commercial fishing. Innovations that were pure experiments when reported at the 1957 Conference have proved themselves and are now widely used. Other innovations and developments have occurred and many more studies have yielded further data on existing gears.

These are dealt with in the present book which comes as a result of the Second FAO World Fishing Gear Congress, which was held in London at the kind invitation of Her Majesty's Government in the United Kingdom in May, 1963. Though this Congress dealt with fewer subjects than the former one in 1957, the book contains more matter, despite considerable condensation. This comes about because subjects are dealt with in 'depth', much more detailed work having been done than heretofore. It is hoped that this book, in its turn, will serve to further stimulate interest and progress in its field and be useful to the fishing industry in decision making.

While dealing with Materials, Gear and Fishing, and Gear Research in some 88 papers, certain trends stood out. Two of these were the emphasis which the Congress placed upon (1) rational gear research and (2) the standardization of testing methods. It was felt that much more should be done on these lines to supplement the trial and error approach. Another is the work that is reported on the hydrodynamics of trawls. Much has been learned about the movement of gear through water and the efficiencies that may be obtained, but it is found that it does not follow that the hydrodynamically perfect trawl will necessarily be the best fish catcher. This depends upon the reaction of the fish themselves towards moving bodies. This is an aspect of fish behaviour—a subject which, in spite of its difficulties, is attracting increased attention, though one might say that it has scarcely begun.

When one goes over the papers in this book one is impressed with the growing complexity of gear technology, as well as the growing demands upon the skippers who use it. Though there is still a great deal of subjective judgment in successful fishing, these judgments are being aided increasingly, if not being gradually supplanted, by the intricacies of instrumentation. Aviators faced the same situation yesterday. Successful flying used to be done 'by the seat of the pants', but this is gone today.

This points to the need for better instruction in the training of skippers in a wide range of techniques and of instrumentation as modern fishing vessels become more complex. It is only in this way that the increased expenditure of the capital required can be justified. Perhaps this book may be useful in this respect. Once again on the matter of training, the facilities offered to

gear technologists are meagre. Only a few countries have gear research institutes at the present time. As has occurred in other kinds of oceanographical research, perhaps the gear scientists will find it profitable to organize team work between their institutions, so that they may share their skills and observations, especially in the more expensive and more complex operations.

The papers embodied in this book come as a result of much patient work on the part of both the authors and the Secretariat of FAO, who devised and organized the Congress. It is gratifying to think that the two years spent in preparation have yielded this result. Again, it is fortunate that the Congress took place in London. The Ministry of Agriculture, Fisheries and Food and the Foreign Office generously placed their services at the disposal of FAO, and many thanks are due to the Fisheries Secretary, Mr. Hugh Gardiner, and his staff for the excellent arrangements. It was fortunate, too, that the Congress coincided with the First World Fishing Exhibition which, through the courtesy of World Fishing, enabled the participants to view the latest improvements in fishing materials and equipment.

DR. D. B. FINN,
Director, Fisheries Division,
Food and Agriculture Organization
of The United Nations

Rome, January 15, 1964.

PART 1

MATERIALS FOR NETS AND ROPES

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Standardisation of Terminology and Numbering Systems for Netting Twines

Abstract
Some terms and definitions of netting twines recommended by the International Organisation for Standardisation are reviewed, as well as presently used twine numbering systems, and the need for an internationally accepted numbering system is pointed out. The tex-system, recommended by ISO, expresses the mass in grams for a unit length of 1,000 m of yarn or twine, and has the advantage, as an international unit, that it is based on the metric system and gives a direct estimation of the twine size, as the heavier the twine is the greater the tex value becomes. For the purpose of defining a simplified but generally useful numbering system for netting twines, the author then discusses the relevant characteristics of netting twines in relation to the information required by the fishermen, netmakers and gear technologists. There are two basic ways of describing twines by the tex-system; the most detailed one gives the tex value of each yarn and the number of yarns and plies, e.g., 23 tex × 5 × 3. To give the weight per unit length of the twine, further information must be given as to the degree of twisting and chemical treatment. The simpler form gives only the resultant linear density of the twine, called R tex, i.e., the actual weight in grams of 1,000 m of the twine. This value includes the effect of twisting operations, and will thus replace the conventional indication of runnage (m/kg and yds/lb). The author feels that R tex alone does not provide sufficient information in the case of thin twines but would be adequate for thicker twines. The complicated and multiplex construction of braided twines and of twines made of dissimilar components only allow designation by R tex values.

Standardisation de la terminologie et des systèmes de numération pour les fils de filets

Résumé
Quelques termes et définitions de fils de filets recommandées par l'Organisation Internationale de Standardisation sont récapitulées ainsi que les systèmes de numérotage utilisés internationalement. Le système tex, recommandé et approuvé par l'"OIS" donne la masse en grammes par unité de longueur de mille mètres de fil de caret ou de fil retordu. Ce système a l'avantage d'être basé comme toutes les unités internationales sur le système métrique et donne une estimation directe de la mesure du fil puisque plus lourd sera le fil, plus grande sera la valeur en tex. Pour définir un système de numérotage simplifié mais utilisable dans la fabrication de filets, l'auteur examine les caractéristiques applicables aux fils de filets en relation avec les informations demandées par les pêcheurs, les fabricants de filets et les techniciens de pêche. Il y a deux manières de base pour décrire les fils retordus par le système tex; la plus détaillée donne la valeur en tex de chaque fil et le nombre de fils et de brins, c'est-à-dire, par example: 23 tex × 5 × 3. Pour obtenir le poids par unité de longueur d'un fil retordu, on a besoin de données sur le degré de retordage et le traitement chimique. Le système plus simple donne seulement la densité linéaire résultant du fil retordu, appelée R tex, c'est-à-dire le vrai poids en grammes de 1000 m de ce fil retordu. Cette valeur comprend l'effet du retordage et remplacera l'indication conventionnelle m/kg et yds/lb. D'après l'auteur l'indication en R tex seule, ne donne pas asses d'informations dans le cas des fils fins mais décrit d'une façon adéquate les fils lourds. La construction compliquée et multiplex des fils tressés et des fils composes de matieres dissemblables admet seulement la désignation par les valeurs R tex.

Normalización de la terminologia y de los sistemas de numeracion de hilos para redes

Extracto
Se reseñan apelaciones y definiciones de hilos para redes recomendadas por la Organización Internacional para Normalización, sistemas de numeración de hilos empleados actualmente y se pone de relieve la necesidad de disponer de un sistema de numeración aceptado internacionalmente. El sistema tex, recomendado por la OIN, expresa la masa en gramos por unidad de longitud de mil metros de hilo; como patrón internacional tiene la ventaja de que se basa en el sistema métrico y de que da una estimación directa del tamaño del hilo ya que cuanto mayor es éste más grande es el número tex. Para definir un sistema de numeración de hilos para redes sencillo y de utilidad general, el autor examina las características principales de dichos hilos con respecto a la información que necesitan pescadores, fabricantes de redes y técnicos en material de pesca. Existen dos maneras principales de describir hilos por el sistema tex; el más detallado da el número tex y torsión en cada hilo, por ejemplo: 23 tex × 5 × 3. Para poder dar el peso por unidad de longitud se necesita más información respecto al grado de torsión y tratamiento químico. La forma más sencilla sólo da la densidad lineal resultante del hilo, llamada R tex, es decir: el peso real en gramos de mil metros de hilo. Este número no sólo comprende el efecto de la torsión, con lo que sustituirá la indicación normal de m/kg y y/lb. Considera el autor que el número R tex solo no facilita suficiente información en el caso de hilos finos pero basta para los más gruesos. La complicada y múltiple fabricación de hilos trenzados y ole materiales distintos sólo permite que sean designados por números R tex.

by
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1. TERMINOLOGY FOR TWINES

As this paper is written for the fishing and not the textile industry, only those terms are defined which should be used for communications in the English language for international trade with fishing gear, in the exchange of information between fishery scientists and in the literature of fishery science. The following terms and definitions are based on recommendations of the International Organisation for Standardisation (ISO Refs. 6 and 7).

1·1 Material for fishing nets

(a) **Discontinuous fibres** (or staple fibres), which may be combined by twisting to form spun yarn.
(b) **Continuous filaments**, which are usually, but not always, combined by twisting to form filament yarn, also described as multifilament yarn.
(c) **Monofilaments**[1], continuous filaments which have greater diameter and stiffness than those used in

[1] By ASTM Standards, monofilament is a "single filament of sufficient size to function as a yarn in normal textile operations". (Ref. 1).

multifilament yarn. They may be used singly to make netting such as for fine gillnets, in which case the "yarn" consists of only one monofilament. Two or more monofilaments may be twisted together to form folded monofilament yarn (or plied monofilament yarn).

1·2 Single yarn is "the simplest continuous strand of textile material" (Ref. 6). The term "yarn" is a general term; when meaning the components of the final product the term single yarn should be used.

1·3 Netting twine. At the first meeting of the sub-committee "Textile Products for Fishing Nets" of the ISO Committee "Textiles" on 23 May, 1962, in Hamburg, it was suggested that the term netting twine should be used instead of "net twine", "fishnet twine", "fishing twine" or other terms, as the general term for any kind of yarn or combination of yarns (including braided) usable for the manufacture of netting (Ref. 7). Fishing nets will seldom be made of single yarns. The usual netting twines are:

Folded yarns (or plied yarns)
Cabled yarns
Braided twines.

The terms "strand" (as a component of twisted twine) and "cord" should not be used.

Netting twine in the form of folded yarn (plied yarn) consists of two or more single yarns twisted together by a single twisting operation.

Netting twine in the form of cabled yarn is made by two or more twisting operations. Firstly, two or more single yarns are twisted together to form a folded yarn (plied yarn) and then two or more of these folded yarns are twisted together to form the cabled yarn (Fig. 1). For very strong netting twines, cabled yarns can be combined by a third twisting operation.

Netting twine in the form of braided twine. A variety of single yarns or of folded yarns may be combined in the braiding process. The possibilities of varied constructions are greater than with the twisted twines (see 6·3).

2. NUMBERING SYSTEMS FOR NETTING TWINES

2·1 Conventional systems

There are many systems in use throughout the fishing industries of the world. The most important are probably:

The international denier system (Td)
The metric count (Nm)
The English cotton count (Ne_C)

The international denier system gives the weight in grams of 9,000 m of single yarn. This system seems to obtain in all countries. It is used for netting twines made of continuous synthetic filaments and (Ref. 13) also for silk twines. Example 1: 210 den×5×3 (abbreviated: 210 den×15).

The metric count is the number of kilometres of the single yarn which weigh one kg. It is mainly used in European fishing industries for cotton netting twines and for netting twines made of discontinuous (staple) synthetic fibres and in some countries for hemp netting twines. Also netting twines made of continuous filaments are so described. Example 2: Nm 20/5/3 (abbreviated: Nm 20/15).

The English cotton count of a single yarn is the number of hanks, each of a length of 840 yds, which weigh one English pound (lb). The system is used in Great Britain, U.S.A., Japan, Canada and other countries for cotton twines and for twines made of discontinuous (staple) synthetic fibres. Example 3: Ne_C 20/5/3 (abbreviated: Ne_C 20/15).[2]

2·2 Conventional systems of less importance or restricted use

The English linen count (lea) of a single yarn is the number of hanks, each of a length of 300 yds, which weigh one English pound (lb). It is used for netting twines made of ramie and flax (Refs. 2, 3 and 13).

The equivalent English cotton count (C.20). In this system yarn count is related to a yarn of Ne_C20. It is used especially in Japan.

"The numbers of yarn for C.20-equivalent twine are obtained by dividing the total denier of the twines with the thickness of the C.20-equivalent. It should be remembered, however, that the thickness C.20-equivalent determined for these twines does not necessarily represent, in a strictly physical sense, the true thickness of cotton 20's." (Ref. 12). In Canada and the U.S.A. "medium-laid, continuous multifilament synthetic twines are numbered according to what the manufacturer thinks is the equivalent Ne_C cotton twine, although there is disagreement as to what constitutes equivalence". (P. J. G. Carrothers).

The rope-yarn number m/kg (N_t or N_R) is used in some European countries, for instance in Germany (Ref. 9) for trawl twines made of manila, sisal and synthetic filaments. Example 4: N_t 3/900 (three single yarns are connected in the netting twine; each single yarn with a length of 900 m has the weight of one kg).

The yards per pound number is used for trawl twines in Great Britain and Canada and, to some extent, for seine twines in Canada.

[2] In the examples 1, 2 and 3, the first figure denotes the single yarn count, the second figure the number of single yarns constituting the folded (plied) yarn and the third figure the number of folded yarns constituting the final product (netting twine). In the international denier system, which is a direct numbering system, the figures are connected by the multiplication sign ×. If an indirect system is used (Nm and Ne_C) they are separated from each other by the solidus (oblique stroke) /.

Hemp yarn may be identified by the number of pounds per spindle (14,400 yds); (Ref. 3).

The diameter in millimetre or inch is generally used for monofilaments.

The runnage in m/kg in yds/lb or in g/100 m (the fatter e.g., in Italy) of the final product (netting twine) is of great importance for netmakers and fishermen. It is generally used in connection with other count systems.

This survey is not complete. In nearly all countries further methods of identification of netting twines are used, though not all of them can be classed as numbering systems. Manufacturers, for instance, sometimes denote their products with letters A, B, C . . . or with Figs. 1, 2, 3 and so on. On the other hand, fishermen often prefer their own traditional denominations, taking little heed of the other systems. (Ref. 13). At the first FAO Fishing Gear Congress the need was expressed for replacing the various numbering systems by a single system applicable to all kinds of netting twines. The general adoption of such a system on an international scale would avoid confusion and facilitate international trade and the exchange of information between fishery technicians. Because of its many advantages and its acceptance as universal yarn count system by the textile industry, the tex-system established by ISO should be used for netting twines.

3. THE TEX-SYSTEM

In 1956, Technical Committee Textiles of International Organisation for Standardisation agreed to recommend a direct system based on metric units for international adoption in place of the various traditional methods of numbering. The basic unit of the new system is the tex. "The linear density (or number) of a yarn in tex expresses the mass in grams of yarn having a length of one thousand m. Thus a thread designated one tex has a mass of one gram per thousand m of its length." (Ref. 5).

$$1 \text{ tex} = \frac{1 \text{ g}}{1{,}000 \text{ m}}$$

The higher the tex value, the heavier the yarn. The numerical value is followed by the term "tex", e.g., 23 tex.[3]

Formula for converting the various conventional yarn numbers into the tex-system (Ref. 5):

$$\text{tex} = 0{,}1111 \times \text{Td} = \frac{1000}{\text{Nm}} = \frac{590{\cdot}5}{\text{Ne}_C} = \frac{1000000}{\text{m/kg}} = \frac{496055}{\text{yds/lb}}$$

(Td = international denier system; Nm = metric count; Ne_C = English cotton count)

In order to facilitate the conversion into the tex-system the following conversion tables are given with values rounded off according to ISO (Refs. 4 and 5):

[3] In order to avoid mistakes, the multiple (kg per 1,000 m) and sub-multiple (milligram per 1,000 m) of the tex unit should not be used for the fishing industry. It seems to be better for netmakers and fishermen to have only one unit for designating all sizes of single yarns and netting twines.

TABLE I—Conventional numbers and tex values

Td = tex	Nm = tex	Ne_C = tex	m/kg = tex
70 = 7·6	200 = 5	120 = 5	5000 = 200
75 = 8·4	160 = 6·4	100 = 6	4500 = 220
90 = 10	120 = 8·4	90 = 6·4	4000 = 250
100 = 11	100 = 10	70 = 8·4	3600 = 280
110 = 12	90 = 11	60 = 10	3000 = 340
125 = 14	85 = 12	50 = 12	2500 = 400
150 = 17	70 = 14	40 = 15	2250 = 440
180 = 20	60 = 17	30 = 20	2000 = 500
190 = 21	50 = 20	26 = 23	1800 = 560
200 = 22	43 = 23	20 = 30	1600 = 640
210 = 23	36 = 28	12 = 50	1500 = 680
250 = 28	34 = 30	10 = 60	1400 = 720
265 = 30	30 = 34	8 = 72	1200 = 840
300 = 34	20 = 50	6 = 100	1000 = 1000
420 = 46	18 = 56		900 = 1100
630 = 69	14 = 72		800 = 1250
840 = 92	10 = 100		750 = 1300
1000 = 110			700 = 1400
1100 = 120			600 = 1700
			500 = 2000
			400 = 2500
			350 = 2800

4. DESIGNATION OF TWINES

4·1 Technical description

A complete technical description of a twine in the form of folded yarn (plied yarn), based on the linear density of the single yarn, comprises (Ref. 6):

Linear density (number) of the single yarn in tex
Direction of twist of the single yarn (Z or S)
Amount of twist of the single yarn (expressed as the number of turns per metre, or of turns per inch, of the twisted single yarn)
Number of single yarns twisted together
Direction of folding (plying) twist (Z or S)
Amount of folding (plying) twist (t/m or t/i)
Example 5 (Ref. 6): 34 tex S600 × 2Z400; R 69·3 tex.

For twine in the form of cabled yarns the following data must be added:

Number of folded (plied) yarns cabled together
Direction of cabling twist (Z or S)
Amount of cabling twist (t/m or t/i)
Example 6 (Ref. 6): 20 tex Z700 × 2S400 × 3Z200; R 123 tex.

In examples 5 and 6 the values R 69·3 tex and R 123 tex are the resultant linear densities of the twines. They are given for additional information and separated from the proceeding parts of the twine counts by a semi-colon. The symbol R is set before the numerical value (Ref. 6).

4·2 Resultant linear density

The resultant linear density is the linear density (tex number) of the final product (netting twine) resulting from twisting, folding or cabling operations. It takes into account the increase in mass per unit length by the twisting (or braiding) operations.

Resultant linear density is greatly dependent on the amount of twist of single yarns, folded yarns and the final product. Some examples for netting twines made of polyamide filaments (without chemical treatment) are given in Table II. In column 2 of this table the product of single yarn tex × number of yarns is given. The values in column 3 are the coefficients of twist α of the final products which are netting twines in the form of cabled

yarn. The degrees of twist of single yarns and folded yarns have not been considered. The values of α have been calculated by means of the formula:

$$\alpha = \frac{\text{turns/metre}}{\sqrt{\text{Nm}}}$$

Nm is the metric number of the twine. The actual resultant linear densities in column 4 are rounded arithmetic means of different numbers of test results.

TABLE II—Coefficients of twist and resultant tex values

1 Twine construction	2 Yarn tex × number of yarns	3 coefficient of twine-twist, α	4 Measured R tex	5 Increase in number %
23 tex×2×3 (23 tex×6)	138	118	149	8·0
		136	152	10·1
		168	172	24·6
23 tex×4×3 (23 tex×12)	276	129	299	8·3
		145	309	12·0
		166	332	20·3
23 tex×5×3 (23 tex×15)	345	127	368	6·7
		189	423	22·6
		238	450	30·4
23 tex×6×3 (23 tex×18)	414	126	456	10·1
		179	489	18·1
		218	510	23·2
23 tex×7×3 (23 tex×21)	483	122	529	9·5
		162	558	15·5
		216	618	28·0
23 tex×8×3 (23 tex×24)	552	141	614	11·2
		198	703	27·3
23 tex×9×3 (23 tex×27)	621	134	681	9·7
		247	725	16·7

5. SELECTING A NUMBERING SYSTEM FOR NETTING TWINES

In selecting and recommending an international numbering system, the following points of view should be taken into consideration:

5·1 The number of a netting twine is only one of the specifications fishermen give when ordering netting twine and netting. The fibre material, e.g., cotton or nylon, must, of course, also be mentioned. Other additional information concerning properties of the twine, e.g., its thickness or breaking strength, may be given too. But these details do not belong to the number of the twine.

5·2 The new system should be based on the tex values and on the recommendations of the International Organisation for Standardisation but, for use in the fishing industry, simplifications are necessary. The complete twine count (see examples 5 and 6) is useful for the manufacturers of twine and netting and for fishing gear technologists but not very practical for the fishermen and most of the net distributors.

5·3 In order to facilitate the introduction of the new system into the fishing industry, traditional methods of notation should not be entirely disregarded. They should be respected to a certain extent if they are not in contrast to the principles of the new system (see point 7).

5·4 Proposals for simplification (if some details of twine construction must be indicated): The meaning of the numerical values of the amount of twist is scarcely known by fishermen and, therefore, should not be indicated. A general term, such as soft-laid, medium-laid, hard-laid, would be preferable. The twist direction of the final product only is, to some extent, of importance to the fisherman and netmaker but not the twist direction of the components of the twine. With twines in the form of cabled yarns it is not necessary to give the numbers of the single yarns and of folded yarns separately but only the total number of single yarns. This notation is already spread in Japan, Italy and Germany and in many other countries. Examples for this simplified twine indication are given in Table II, column 1, in brackets (Ref. 10).

5·5 Netmakers and fishermen often require the weight of the netting twine. Resultant tex values can be used for calculating the weight of netting twine and netting and thus also the price. In the new system they should replace the twine runnage (m/kg or yds/lb) which should no longer be used.

6. NUMBER NETTING TWINES ONLY BY RESULTANT TEX (R TEX)

There are recommendations for simplifying the designation of netting twine to one value only: the resultant tex.

On account of the influence of twisting, R tex cannot be determined by only multiplying the yarn tex (as in column 2 in Table II). Proposals have been to approximate the R tex value by applying a correction as twist factor of 10 per cent which often holds true for medium-laid twines. But the resultant linear density should be indicated with sufficient accuracy as the weight of 1000 m of the twine to be used as a basis for calculating the weight of netting. This R tex value basing on the actual weight of the twine could be used alone for thick trawl twines (see 6·1), for twines of dissimilar components (see 6·2) and for braided twines (see 6·3).

6·1 Thick netting twines

The actual R tex values could be used singly, without additional description for designating the thick netting twines of big bottom trawls.

Examples for strong twisted trawl twines made of continuous polyamide:

R 8000 tex (125 m/kg)	R 3000 tex (333 m/kg)
R 6250 tex (160 m/kg)	R 2500 tex (400 m/kg)
R 5000 tex (200 m/kg)	R 2000 tex (500 m/kg)
R 4000 tex (250 m/kg)	R 1650 tex (600 m/kg)
R 3333 tex (300 m/kg)	

Here the differences between the numerical values are so evident that the kinds of twine may be clearly separated from each other by the R tex. If necessary, the direction of twist of the twine may be put at the end, e.g., R 8000 tex S.

6·2 Netting twines of dissimilar components

These are produced mainly in Japan and are of some importance for the fishing industry. They may be composed of yarns made of different kinds of fibres (e.g.,

'Livlon', made of polyvinylidene chloride and polyamide fibres, or 'Marlon', made of polyvinyl alcohol and polyamide fibres) or of spun yarns and filament yarns of the same kind of fibre. The clear notation of such twines being very complicated (Ref. 6), they should be numbered by R tex with additional information concerning the fibre material.

6·3 Braided netting twines

They are generally round or tubular braided, but braids of flat structure are also manufactured for fishing nets. There is an infinity of construction possibilities for these twines:

The number of strands, braided together, depends on the number of bobbins of the braiding machine (e.g., 6, 8, 12, 16, or others).

The strand may consist of one or more (Fig. 2) yarns, twisted together or not.

Each strand may include the same number of yarns or not.

The braid may contain a core (Fig. 2) or not.

The core may consist of only one yarn, or of several yarns, twisted together or not.

The core yarns may be of the same count as those of the strands or of another fineness.

This complicated structure of braids does not allow a simple notation. Only resultant tex can give a practical and useful designation.

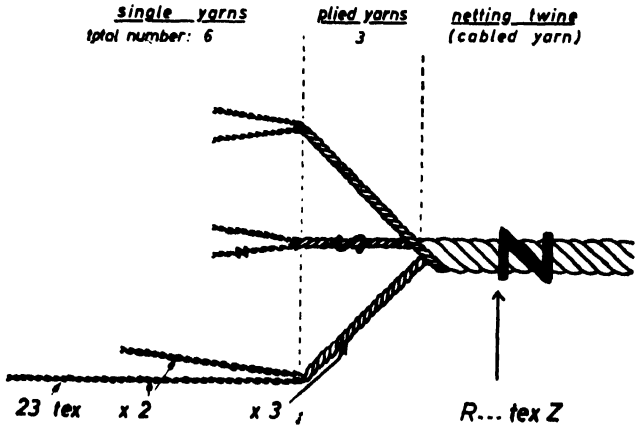

Fig. 1. Construction of a netting twine in the form of a cabled yarn.

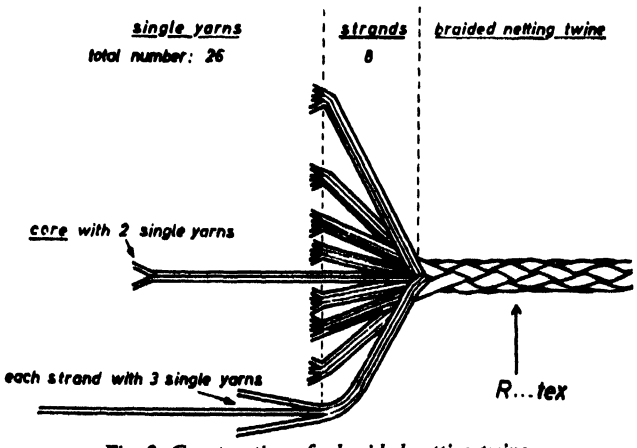

Fig. 2. Construction of a braided netting twine.

7. IN FAVOUR OF DETAILED DENOTATION

As can be seen from Table II, the R tex values of netting twines of the same single yarn tex and the same number of yarns but with different amount of twist can differ in a high range. It is even possible that a hard-laid twine with a lower number of single yarns has a higher R tex than another soft- or medium-laid twine containing more single yarns. (See the examples 23 tex × 21, 23 tex × 24 and 23 tex × 27 in Table II.)

The resultant tex alone does not supply full indication in most cases and netting twine, except those mentioned above (see points 6·1-6·3), should therefore be designated by the count of the single yarn and the number of single yarns constituting the twine and, additionally, by the resultant tex. (See Fig. 1.)

There is another reason for suggesting this notation: If the types of fishing gear are classified according to the strain on the net material (Ref. 8) most of them belong to the medium-strained group, e.g., seines and purse seines, bottom trawls of small vessels, most midwater trawls, gillnets for herring, cod and salmon, most river stownets, dipnets, fykenets, trapnets, castnets and so on. Studying fishery literature we can find that the netting twines for these types of gear are nearly always designated by the single yarn count and number of single yarns. The systems used may be different (Td, Nm, Ne or others) and so may be the way of writing the notation but nearly always we may find the two components (often supplied by the runnage in m/kg or yds/lb).

Fishing industry, netmakers and distributors are accustomed to this method of numbering; they are not textile experts; for them the number of a netting twine is what they ask for when ordering so as to receive a twine of a certain construction and breaking strength. Numbers such as Td 210 × 15, Nm 20/15 or Ne 20/15 are names of these kinds of twine well known to the fishing industry. This should be taken into account when introducing the tex-system. Example: 23 tex × 5 × 3; or simplified: 23 tex × 15; R 380 tex Z. Here, "23 tex × 15" is the unchanging fixed nominator of the twine, similar to the conventional systems used in most countries and therefore easily understandable to the fishermen. The resultant tex value, rounded to a certain degree, changes according to the amount of twist and may be used for calculating the weight of twine and netting.

8. CONCLUSIONS

All numerical values of netting twines should be given in tex.

The resultant tex value (R tex) could be used alone for those types of netting twine which are unmistakably identified by this notation or have a complicated construction (as e.g., braided twines or twines of dissimilar components). It should replace the conventional runnage in m/kg or yds/lb.

Types of twine which are not unmistakably identified by R tex alone should be designated by single yarn count in tex, number of single yarns and, additionally, by the resultant tex. (As in Fig. 1.)

If necessary, the direction of twist (S or Z) of the netting twine could be put at the end of R tex, as well as "soft-" "medium-" or "hard-laid".

Acknowledgments

The author wishes to thank the following experts for their very useful advice and comments: Dr. Arzano (Italy), Mr. Carrothers (Canada), Mr. Hentschel (Germany), Mr. Lonsdale (Great Britain), Dr. Reuter (Netherlands) and Prof. Takayama (Japan).

Not all of them concur in all details with his opinion.

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DISCUSSION

Dr. G. Klust (Germany) Rapporteur: Following the expressed desire of the participants at the First Gear Congress (1957) that the different numbering systems should be replaced by one single International system usable in all countries and applicable to all kinds of net materials, a working party was established to review the position and make a recommendation. Its Chairman, Mr. Lonsdale, submitted a report in December 1960 of which the conclusions were that the universal system might be either a conventional system, preferably metric, or an entirely new one in which case the tex-system should be selected.

Today the decision is in favour of the tex-system which the textile industries of many countries have already accepted. The netting industry is only a small special branch of textiles. It is therefore important that the tex-system should be accepted by the fishing industry without further discussion. The unit of the tex-system is the "tex" based on metric values. The linear density, or the number of a single yarn, in tex expresses the mass in grams of a yarn having a length of one thousand metres. For instance, 23 tex means a single yarn, which, with a length of 1,000 metres, weighs 23 grams. Besides this unit "one tex" the International Organisation for Standardisation recommends two other units; one is the multiple of tex, kilotex, meaning kilograms per thousand metres and the other is the sub-division of tex, millitex, meaning milligrams per thousand metres. But I propose that these further terms be not used in fishing in order to avoid new confusion. It would seem to be better to have high numerical values in tex for thick twines than to number by kilotex, and the lighter twine by tex or millitex.

The advantages of the tex-system are that it is direct and can be applied to twine as well as yarn. Because of the advantages outlined in detail in the paper the sub-committee "Textile products for fishing nets" of ISO, has resolved to recommend the following notations for netting twines.

Notation may give details of the single yarns making up the product

(e.g., 23 tex × 5 × 3 ; R 380 tex)

or when especially constructed twines are described, may be limited to the resultant count and final twist direction

(e.g., R 380 tex S)

or when describing braided twines, may give the resultant count alone

(e.g., R 380 tex).

Netting industries and fishing industries should accept these notations and FAO should support them. Manufacturers of twine and netting should use, in the first place, the tex value and then the conventional number, maybe in brackets.

Mr. A. Robinson (UK) questioned the wisdom of the recommendation that the term "strand" should not be used to indicate ply in the twine. He thought, to the trade generally, it would be clearer than the alternative of "folded yarn". "Strand" was well known because of its use in ropes where it was the standard term. In relation to the claim that the description should be "unmistakable" he pointed out that if the term was given up, it could leave doubt as to whether twine was two ply or three ply—it could be 6 × 2, 4 × 3, or 3 × 4—and manufacturers would often be left to guess.

Dr. von Brandt: These points have been considered and the measures suggested are deemed to be most suitable.

Mr. B. M. Knox (UK): Since the introduction of synthetic fibres there has been a great advance and most manufacturers do now designate twine in either metres per kilo, or yards per lb which is an advance on the old method. This data does assist the fishing industry in understanding the selling numbers of twine. My company will work with others to achieve some sort of standardisation.

Dr. Klust summing up, stressed that descriptions must be as simple as possible. The terms "ply" or "fold" are recommended by ISO for International use. "Strand" is generally used for the components of ropes only and not of twines. If the first twine numbering proposal of ISO sub-committee is accepted (example: 23 tex × 5 × 3), it could leave no doubt as to the number of plies. The amount of twist of yarn, ply and twine has a great effect on the properties of netting twine (as can be seen from tables in the paper). But fishermen do not understand numerical values of twist given in turns per metre or per inch and only need to know the direction of the twist of the final product, the netting twine as well as the the terms "soft", "medium", or "hard". The problem of trade names was only one for the manufacturer of fibres. The main problem was to introduce the tex unit and that depended on the manufacturers of twine and netting. The question of how to write the number of twine is of secondary importance.

Test Methods for Fishing Gear Materials (Twines and Netting)

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Abstract

The present paper is the result of the Working Party on Testing Methods set up during the first FAO World Fishing Gear Congress and of a recommendation made by the ISO Sub-committee 9—Textile Products for Fishing Nets. It represents an effort at unification of the various methods used for testing the characteristics of fishing twines and netting, resulting from the suggestions and exchange of ideas of many gear technologists working in this field. For twines the testing methods used in the textile industry can be employed; however, properties in the wet condition are of main importance in fishing gear. Special methods have to be developed for testing fish netting, since no applicable textile methods exist. The testing methods described cover both physical, chemical and biological tests, and for each item define a characteristic to be tested, and the range and accuracy of the instruments to be used. The report covers testing of netting materials for the various forms of breaking strength, elasticity, elongation, extensibility, flexibility, abrasion resistance, weight (under different environmental conditions), length and thickness, effect of heat, weathering, chemicals and deterioration of a biological nature. The paper furthermore includes suggestions towards uniform methods for testing the properties of netting such as mesh size, strength, knot stability and weight under the various forms applicable to fishing nets. It had been the intention of the FAO Secretariat to bring this matter to the Congress ready for discussion, aimed at definite recommendations towards an internationally agreed standardisation of testing methods for fishing twines and netting. For the testing of some properties, a final selection has not been made from among the two or more alternative testing methods described. Apart from these few exceptions, the report suggests one set of definitions, type of equipment and methodology for testing the characteristics of netting twines and netting, and it is hoped that these will be accepted as standard in the trade and among fisheries technologists.

Epreuves sur materiaux textiles utilises dans les engins de pêche

Résumé

La présente communication est le résultat du Groupe de Travail sur les Méthodes d'Epreuves organisé pendant le Premier Congrès Mondial des Engins de pêche et d'une recommandation faite par le sous-comité 9 (Produits textiles pour filets de Pêche) de l'Organisation Internationale de Standardisation. Elle traduit un effort tendant à unifier les différentes méthodes utilisées pour éprouver les caractéristiques des fils et filets de pêche et est le résultat d'échanges d'idées entre de nombreux techniciens des pêches travaillant dans ce domaine. En ce qui concerne le fils, les méthodes utilisées dans l'industrie textile sont valables cependant il est très important de rechercher des méthodes pouvant être appliquées dans le domaine des pêches à des fils mouillés. Les méthodes d'essais décrites couvrent en même temps les tests physique, chimique et biologique et pour chacun, définissent les caractéristiques à éprouver et aussi la portée et la précision des instruments à utiliser. Le rapport traite également des épreuves des matériaux de filets, des différents aspects de force de rupture, élasticité, allongement, extensibilité, flexibilité, résistance à l'usure, poids (sous différentes conditions d'environnement), longueur et épaisseur, effets thermiques, atmosphériques, chimiques et détérioration de nature biologique (animaux marins). En outre, la publication contient des suggestions pour l'unification des méthodes d'épreuves, dimensions des mailles, résistance à la rupture, stabilité des noeuds et poids sous différents aspects, applicables aux filets de pêche. Le Secrétariat de la FAO avait l'intention de porter cette question au Congrès, prête pour discussion et arriver ainsi à des recommandations définitives internationales pour la standardisations des méthodes d'épreuves des fils et filets mais pour les épreuves de certaines propriétés, une sélection finale n'a pas encore pu être établie. Le rapport cependant suggère une liste de définitions, type d'équipement et méthodologie pour éprouver les caractéristiques des fils et filets et on espère qu'elle pourra être acceptée comme standard par le commerce et les techniciens des pêches.

Metodos para ensayar los materiales para artes de pesca (hilos y redes)

Extracto

Débese esta ponencia a los resultados obtenidos por el Grupo de Trabajo sobre Métodos para Ensayos creado durante el Primer Congreso Mundial de Artes de Pesca de la FAO y a una recomendación hecha por el Subcomité 9 de la ISO sobre Productos Textiles para Redes de Pesca. Apira a unificar los diversos métodos empleados para ensayar las características de los hilos y redes de pesca, resultado de las sugerencias e intercambio de ideas de muchos especialistas en material de pesca ocupados en este sector. Para los hilos pueden emplearse los métodos de ensayo de la industria textil, pero como lo que más interesa en el material de pesca son sus propiedades cuando está húmedo, se tienen que formular métodos especiales para ello, ya que los de dicha industria textil no son aplicables. Los métodos descritos, físicos, químicos y biológicos, definen para cada caso una de las características que se tienen que ensayar y dan el alcance y exactitud de los instrumentos empleados. Menciona el autor el ensayo de los materiales para redes en cuanto a su resistencia a la rotura, elasticidad, estiramiento, flexibilidad, resistencia a la tracción, peso (en diversas condiciones ambientales), longitud y diámetro, efecto del calor, resistencia a la acción atmosférica y a las sustancias químicas y deterioración de naturaleza biológica. Se hacen también sugerencias para uniformar los métodos para ensayar propiedades de las redes, como tamaño de la malla, resistencia, estabilidad del nudo y peso en las diversas condiciones en que trabajan en la pesca. Intentaba la Secretaría de la FAO someter esta cuestión al Congreso, lista para discutirla, con objeto de que se hicieran recomendaciones definitivas para normalizar internacionalmente, tras previo acuerdo, los métodos para ensayar hilos y redes de pesca. Para la prueba de algunas propiedades todavía no se ha hecha una selección definitiva entre los diversos métodos descritos. Salvo estas excepciones, en la comunicación se propone un grupo de definiciones, clase de material y metodología para ensayar las características de los hilos y las redes y se confía que sea aceptado como patrón en la industria y entre los tecnólogos pesqueros.

AS a result of efforts in all parts of the world to increase the fishing yield, fisheries science has become more interested in fishing methods and fishing gear than ever before. A number of research institutes have been founded specifically to study problems of fishing techniques and others have added such studies to their research programmes. The First International Fishing Gear Congress, convened by FAO in Hamburg, October 1957, demonstrated that this field of study can be approached in many different ways and that great possibilities to improve fishing methods still exist. As a result of these studies, fishing gear will be designed and constructed on a more rational basis and the fishing effort will become more effective.

It is logical not only to study the fishing gear to improve its construction and efficiency but also to study the materials from which the gear is made. In particular, new man-made fibres will continue to be invented and will continually become available for making nets. It is important to test these new netting twines and the netting made from them to assess their usefulness **before** trying them in full-scale fishing gear. For this purpose it must be known what properties of the netting materials are important for fishing gear, and appropriate methods for testing these properties quantitatively must be available. A knowledge of these properties, e.g., of newly developed netting twines, permits a decision to be made whether or not the material can be used in fishing gear and how it can be used to greatest advantage. It is possible to avoid unnecessary and expensive tests with commercial fishing gear if the properties of the netting materials are measured first.

In some cases netting materials and netting can be tested by methods which have already been developed by the textile industry and which, in many instances, have already been standardised. On the other hand, the fishery is often interested in material properties in both the dry and wet conditions, whereas these properties are of little or no interest for usual textile applications and hence have so far not been measured. Thus, the fishery must develop new test methods of its own or modify existing methods to its own purposes.

In the Netherlands, a special institute for fisheries has tested netting materials since 1911. It is interesting that Het Nederlandsche Visscherij-Proefstation en Laboratorium voor Materialen-Onderzoek, Utrecht, was founded by fishermen organisations. In Germany, tests in connection with gear research work began in 1928, and a special institute for fishing technique, now located in Hamburg, was founded in 1936. In Canada, the Fisheries Research Board has been interested in netting properties since 1934, and in 1954 the Canadian Government Specifications Board founded a Committee on Specifications for Fishing Gear at the request of the commercial fishery. In Japan, the Tokai Regional Fisheries Research Laboratory in Tokyo became the centre of fishing gear research, and, in India, the Central Institute of Fisheries Technology, Craft and Gear Wing, in Cochin, should be mentioned in this respect.

Some of these, and other institutions also, have developed test methods for netting materials and netting, often without knowledge of the other's work, and have collected experiences which should be used as the basis for future research. Unfortunately, the methods have either not been published or exist in literature which is difficult to find. Thus, it seems advisable to summarise these test methods for general use.

A Working Party on Testing Methods, founded at the First International Fishing Gear Congress, was asked by FAO to collect all testing methods used for fishing gear materials, with the ultimate objective of establishing international standard test methods for netting twine[1] and netting.

A number of interested countries participated in this Working Party, and the following submitted contributions:

Canada (Fisheries Research Board of Canada).
Denmark (Teknologisk Institut, Kopenhagen).
France (Chambre Syndicate des Filets de France, Paris).
Germany, Federal Republic (Institut für Netzforschung, Hamburg).
Germany, Eastern (Institut für Hochseefischerei, Rostock).
Japan (Tokai Regional Fisheries Research Laboratory, Tokyo).

[1] The International Organisation for Standardisation (ISO) Sub-committee 9, Textile Products for Fishing Nets, has prepared a draft dealing with basic terms and definitions for textile products for fishing nets. In this draft "Netting twine" is defined as a "general term for any kind of yarn or combination of yarns (including braided) usable for the manufacture of netting".

The Netherlands (N.V. Onderzoekingsinstituut Research, Arnheim).
(Het Nederlandsche Visscherij—Proefstation, Utrecht).
U.S.S.R. (Laboratory of Fishing Technique, Moscow).

In addition to these papers, recent contributions, particularly those published in Modern Fishing Gear of the World (1959), have been considered in so far as they are concerned with test methods.

Different methods have reached different stages in their development. Test methods for some properties, particularly those in which the textile industry is also interested, have been highly developed whereas test methods for other properties have been only slightly developed or do not exist at all.

Before adoption, a test method should be proven in practice; its results should correlate well with experience and results in the fishery. It is not possible to develop test methods only in the laboratory. The following collection of methods includes only those which have actually been used in different countries. It is quite possible that, as a result of knowledge gained in the future, certain methods will have to be modified or completely replaced by other methods. As new materials become available, new problems will arise and new test methods will have to be developed to measure properties not yet recognised.

In spite of this, the following collection of test methods for netting twine and netting may be useful to those starting investigations in this field which is so important to the fishery.

TESTING FISHING GEAR MATERIAL

For testing netting it will usually not be possible to base the test method on methods already developed, for example, for woven and knitted fabrics. In most cases, these other materials differ from netting, even from their initial manufacture. The situation is different with netting twine, in the form of yarns, twines, and monofilaments, which may often be tested by methods already standardised as mentioned above (i.e., by national standard methods of different countries such as the ASTM Standards on Textile Materials in U.S.A. or "Deutsche Normen" in Germany, and by the different recommendations of BISFA). Yet, very often, these methods were developed for finer materials such as fibres and yarns and consider only the properties, e.g., breaking strength, in the dry condition. Such tests require a room having standard atmospheric conditions (see below) in order to give comparative results.

It must be emphasised that the precision which is often desirable in the textile industry cannot be achieved, and even may not be required, with the rough materials often used for making nets. Further, the properties of netting materials and netting are usually of interest only in the wet condition. The usual dry strength data, for example, are normally of no value to the fishery and can even be dangerous when they lead to an incorrect decision. Only properties in the wet condition are important. This results in an advantage in testing textile materials for fishing gear because rooms having standard atmospheric conditions are not essential. This fact is of particular interest to those fishing institutes which wish to start testing netting materials and netting.

On the other hand, it cannot be denied that the price of netting twines and netting is usually based on the air-dry weight, and this can be determined accurately only in a properly conditioned atmosphere. It is not good enough to measure moisture content and correct the weight to a standard moisture content because the amount of moisture in the material affects its physical dimensions. For example, a piece of cotton twine is longer when it has a low moisture content than when it has high moisture content so that measuring its runnage (m/kg) when its moisture content is below standard, then correcting the weight to standard moisture content, results in the measured runnage being too high. This error is particularly important if the twine is identified by its runnage (e.g., m/kg) or by its weight (e.g., resultant tex). Thus, a room having standard atmospheric conditions is useful even for testing fishing net materials and netting. However, absence of such a room is not sufficient reason for not starting tests with wet materials.

DRY AND WET TESTS

The standards already established for textile tests specify, as already mentioned, that the specimens be conditioned in a standard atmosphere for at least 24 hours or until the weight becomes constant. The usual standard atmospheric conditions are:

A temperature of 20 ± 2°C (70 ± 2°F) and
A relative humidity of 65 ± 2%.

The test must be performed in the same standard atmosphere as that in which the test specimens were conditioned. Unless extreme accuracy is required, air-dry specimens kept in the normal testing room atmosphere will give dry test results adequate for fishery purposes.

For the much more important wet tests, most investigators immerse the specimens in clear tap water or sea water at ordinary room temperature for at least 12 hours before the test. Tests with netting materials made of cotton, polyvinyl alcohol, polyamide, or polyester show no differences in wet strength whether soaked in distilled water, fresh water, brackish water, or sea water. Net materials and netting samples which have already been used for fishing become soaked in a relatively short time. This is also true with new bast fibres and untreated man-made netting materials. Other natural fibres require more time. Care must be taken that specimens of new netting twines made of cotton or of lubricated hard fibres are really submerged below the surface of the water and do not float without becoming wetted. Soaking must be done in containers which are large enough to permit clear observation that the samples are wholly immersed.

If, under certain circumstances, the specimens must become soaked more quickly, they may be immersed in a solution of a wetting agent.[2] Tests may be conducted after the specimen has been immersed for 15 minutes.[3] These agents often have the disadvantage that they decrease the slipping resistance of the knots, hence, they should be avoided if knots are to be tested.

Tests with netting twines made of polyamide, polyester, or polyvinyl alcohol fibres or polyethylene monofilaments have shown that the time of immersion in wetting-agent solutions has no effect on the results of wet breaking strength tests.

A. Testing of netting materials

The term "netting materials" includes all materials used to make netting. They may be made of natural or synthetic fibres or even of metal wire. They may be monofilaments or they may be twisted or braided[4] into one of many various forms. Traditionally, the terms used by fishermen do not always agree with the definitions used in the textile industry. There have been some proposals for world-wide standardisation of terms used for fishing, especially those for nets.[5] The following remarks may be helpful to an understanding of the meaning of terms used in the textile industry:

"Yarn"—a generic term for continuous strands of textile fibres or filaments suitable for laying, braiding, knitting, weaving, etc., into larger structures. It may be a number of fibres twisted together, a number of continuous filaments laid together with or without twist, or a monofilament. The term "netting yarn" as used in the fishing industry is very often not in accord with this definition.

"Twine"—a balanced, plied yarn made by twisting, laying, or braiding several yarns together. Only multi-ply yarns are called "twines". The term "netting twine" as used in the fishing industry is usually in accord with this definition, but it is not always used by the fishermen.

"Cord"—a balanced structure formed by twisting or laying two or more plied yarns together.

"String"—not generally used in the textile or fishing industries because it does not have a precise definition.

Most tests applied to netting twines or netting may be classed as physical, chemical, or biological, but there are also other tests related to manufacturing, handling, or fishing effectiveness. Many tests have to be conducted with the fishing gear in action, but the following descriptions include only those test methods which may be used in the laboratory.

[2] The term "wetting agent" refers to chemical products which decrease the surface tension of the water so that the water can easily soak into the specimen, displacing the air. Typical wetting agents for textiles are 'Aerosol' and 'Nekal BX' in a 0·1 per cent solution.

[3] Canada specifies that the specimen be soaked for five min (Canadian Government Specifications Board, Specification for Nets: Fishing, 55-GP-1, 25 April, 1958).

[4] The terms "braid" and "plait" both mean "to intertwine or interweave yarns", but "braid" is usually used with reference to twines because "plait" also means "to fold cloth".

[5] See footnote [1].

(a) Physical tests

Most of the netting twine tests under discussion are physical in nature. Surely breaking strength is of greatest interest to the fishery and should be reported in every case. However, there are numerous other physical properties of differing significance. The order in which the test methods are presented in the following is arbitrary and does not imply any relative importance.

(1) Breaking strength

Breaking strength is defined as that load which causes the netting material to break. Wet or dry netting yarns may be tested. As already stated, the dry strength is usually of no interest to the fishing industry but, for its measurement, the test methods standardised in many countries may be used. Otherwise, the methods for wet netting materials described in the following have to be modified to accommodate the dry materials. The test report must state whether the materials were dry or wet at the time of testing.

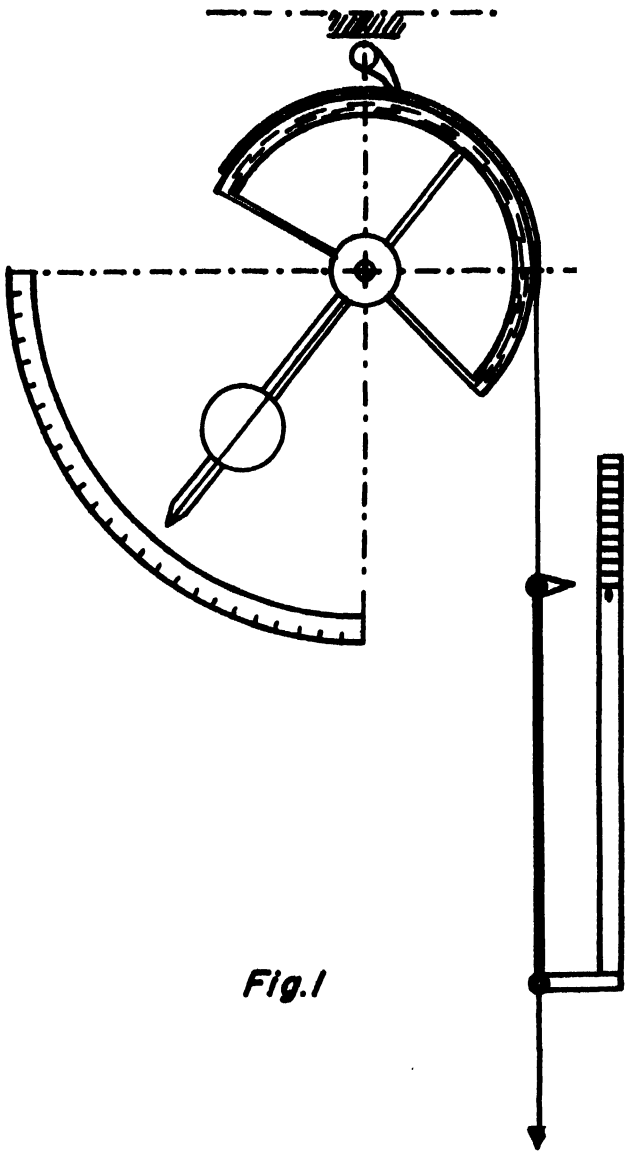


Fig.1

Both the wet strength (e.g., of unknotted twine) and the wet knot strength of the netting material are important to the fishing industry, and special testing machines are required for their measurement.

Strength testing machines: Testing machines known as dynamometers or tensiometers are used to measure breaking strength. The test specimen of netting twine is fastened between two clamps and is stretched by an increasing load until it breaks.

Strength testing machines may be classified as follows into three basic types, according to the way in which the load is applied to the test specimen:

Constant rate of load.
Constant rate of extension.
Constant rate of loading-clamp traverse.

The widely used pendulum-type tester (Fig. 1 and 2) belongs in the last class. The upper clamp is connected with the weighted pendulum which, in turn, is lifted by the increasing tension in the test material. This tension increases irregularly in accord with the elongation characteristics of the material, for tension is reduced as a result of elongation, particularly at the beginning of the test. Similarly, the length of the specimen increases irregularly because the upper clamp moves irregularly in accord with the irregular increase of tension in the test specimen. These pendulum testers have unofficially been called "constant rate of nothing" because, so far as the test specimen is concerned, nothing changes at a constant rate.

The recently designed, electronic, recording dynamometers (Fig. 3) are very precise and accurate because there is no frictional resistance in the tension-measuring unit. In these testers, the first clamp is moved from the second clamp at a constant velocity and the tension is measured by an electrical element to which the second clamp is attached. Only testers with these recording electronic dynamometers give a constant rate of extension because the clamp on the dynamometer moves a negligible amount.[6]

The inclined plane, or constant-rate-of-load, machines can be used only for lighter materials up to 2 kg breaking strength and hence are not generally used for fishing gear materials.

The clamps usually supplied with the testing machines may be used for testing many netting materials. However, if smooth or heavy materials, because of their fibre properties, construction, treatment, or high strength (e.g., twines made of hard fibres or certain man-made filaments), slip in the usual clamps before breaking or break at the clamps, then special clamps (Fig. 4) have to

[6] These electronic testing machines are relatively expensive. For testing only in the field, home-made testers, usually of the spring balance type, may be used. Such testers have been described, e.g., by Czensny and Meseck: Untersuchungen über den Netzfrass niederer Wassertiere, Zeitschrift für Fischerei XXVI, 237-310, 1938; by Park, Y.C. and An, U.H.: Tensile Strength of Netting Cords, Bull. of Pusan Fisheries College II, 4-6, 1958; Miyamoto, H. and Shariff, A.T.: Experiments on Fishing Net Preservation, Indian Journal of Fisheries 6, 145-185, 1959.

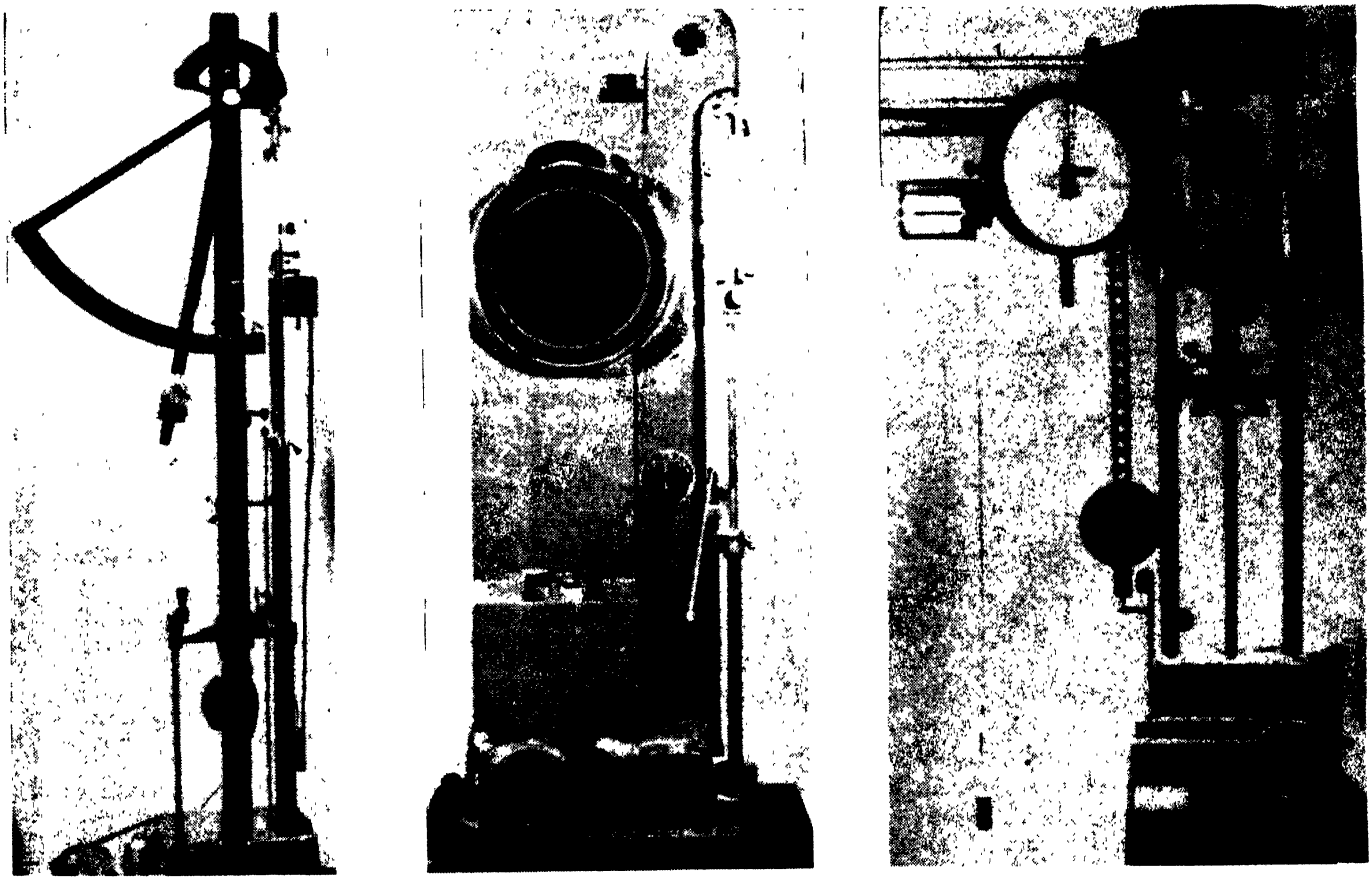


Fig. 2. Pendulum tester:—(a) Koch (Schopper) (0-2, 0-5 and 0-10 kg) (b) Frank (0-10, 0-50 kg) (c) Wolpert (0-100, 0-500 kg).

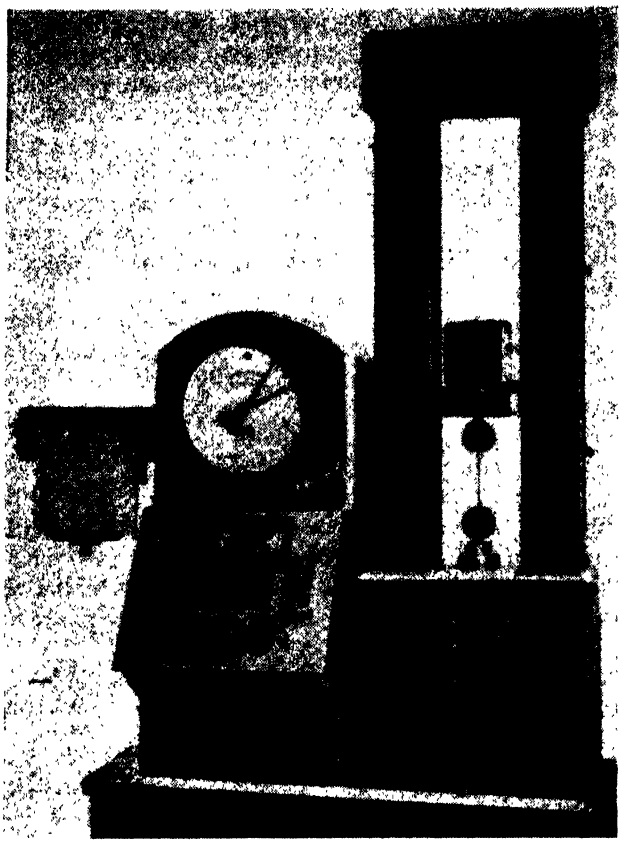
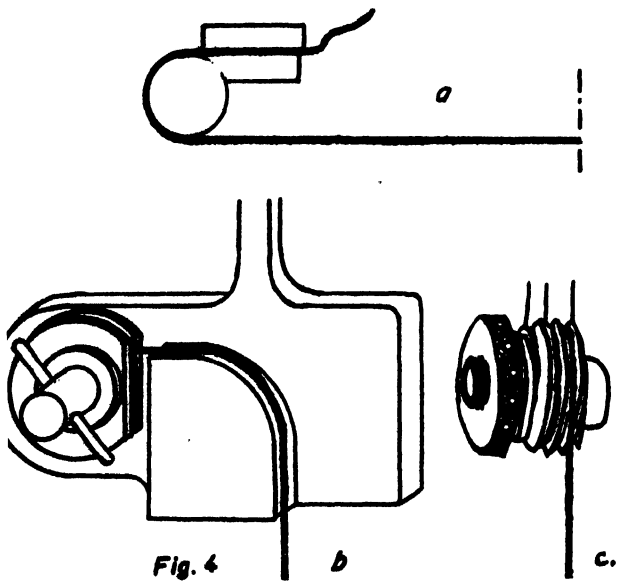


Fig 3. Electronic recording dynamometer 'Testatron' Wolpert.



be used. These must be constructed in such a way as to avoid sharp edges.[7]

If a pendulum-type testing machine is used, its load capacity should be chosen so that the angle of the pendulum from vertical at the time of breaking is not greater than 45° nor smaller than 5°. Further, the average breaking load should lie above the first fifth of the measuring range. The velocity[8] at which the loading clamp moves should be 100 mm/min.[9]

It is convenient to use testing machines with different overlapping ranges for testing netting materials, e.g., 0-2 kg, 0-5 kg, 0-10 kg, 0-50 kg, 0-100 kg and 0-500 kg. To a certain extent the testing range of the same machine may be altered by changing the pendulum weight (by adding or removing weights). To be specific, then, three machines are needed, viz. 0-10 kg, 0-50 kg, and 0-500 kg, and the other ranges may be obtained by changing the pendulum weight.

There is considerable variation in the length of the specimen specified between the clamps at the beginning of the test. For normal clamps this should be 200 mm[10] so that a netting twine sample 30 cm (ca[11] 12 in) long is required for each test. If, as mentioned before, special clamps have to be used for those netting materials which slip or break in normal clamps, the samples may have to be 100 cm (40 in) or more in length depending on the construction of the clamps. The actual test length should still be about 200 mm.

Care must be taken that twisted materials do not lose twist while the test specimens are being cut to the lengths described above.

Wet netting materials are tested at a room temperature of about 20°C (68-70°F). It is suggested that higher or lower temperatures can affect the result, particularly if the material under test has been manufactured from man-made fibres (see Section 9: Thermal Reaction).

The testing machines can become damaged as a result of tests on wet specimens. Therefore, the machines should be dried and oiled very carefully after use.

Wet breaking strength: The netting materials which are to be tested for wet breaking strength are cut into test pieces each 300 mm long and, as described, are immersed in water for at least 12 hours. The netting materials are tested as soon as they are removed from the water. They are straightened and are secured in the clamps of the testing machine with 200 mm actual test length between the clamps. If breaking strength alone is to be tested, it is not necessary to use any particular pre-tension contrary to official standards.

Breaking strength is reported as the average of all test results. Thus, the test specimens should be taken from

[7] See Modern Fishing Gear of the World, p. 77, Fig. 3, and sketch p. 96.

[8] International standards do not specify the rate at which the clamp travels, but, rather, specify that the testing time (time during which the specimen is loaded to rupture) shall be 20 ± 2 sec.

[9] Canada (CGSB Schedule 4-GP-2, Method 9.B), Japan (Modern Fishing Gear of the World, p. 66), and U.S.A. (ASTM Designation: D76-53) specify that the rate of loading clamp traverse shall be 12 ± 0·5 in/min = 30 cm/min.

[10] Canada specifies 10 ± 0·25 in in CGSB Schedule 4-GP-2, Method 9B; Japan specifies 25 cm in Modern Fishing Gear of the World, p. 66, 1959; U.S.A. specifies 10 ± 0·05 in in ASTM Designation: D204-57T. Man-made fibres are usually tested according to BISFA rules, viz. 50 cm between grips and 20 ± 2 sec breaking time.

[11] All conversions from the metric system are approximate.

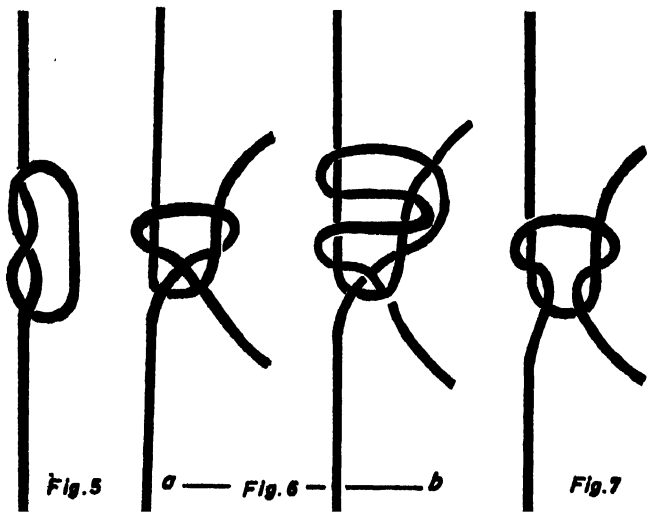
the netting material in such a way that they are representative of the whole lot that is to be tested, e.g., not from the first portion of a spool or strand. In many cases, particularly if a new material is being tested for the first time or if the material is not uniform (e.g., from hard or bast fibres), at least 20 test breaks are required to get a sufficiently precise result. As a rule, 10 test breaks are sufficient for routine tests. Where a series of tests are being performed to show loss in strength by rotting of preserved, natural fibre netting materials, only five test breaks are required for significant results. This is in contrast to the usual procedure for tests of yarns and twines where the number of test breaks is determined by the non-uniformity of the material and by the desired precision of the average. Twenty, ten or five test breaks are sufficient for fishery purposes under the above conditions.

The test result is disregarded and an additional test break is performed if the test specimen slips in the clamps of the testing machine, or breaks in or at the edges of the clamps, or if the result appears to be different from other results in the test as a consequence of unusual or irregular faults in the material.

The breaking strength is reported in kg to two significant figures: averages greater than 1 kg are rounded off to the first decimal place and averages less than 1 kg are rounded off to the second decimal place.

Wet knot breaking strength: In testing wet knot breaking strength, the type of knot is important. In most laboratories, a simple, overhand knot (Fig. 5) is tied in the centre of a single piece of the netting material, because only specially trained people can tie typical netting knots without losing some of the twist in the netting twine. Further, it has been found that the results of tests with knots tied by hand in netting twine do not correlate well with the results of mesh-strength tests applied to netting made by machine using the same knot. The value of tests involving the overhand knot is thereby increased.

In order to test a knot as used for making netting, two pieces of the netting twine under consideration, each 50 cm long, are tied together by the weaver's knot (English knot, Fig. 6a) or by the double knot (Fig. 6b) developed from it. Also, the reef knot (Fig. 7) and other knots may be tested in so far as they are used to make netting.



However, this test cannot always be conducted satisfactorily with all netting materials because the knots sometimes slip under the increasing load and can slip out completely without breaking if only one leg of each side of the knot is secured by the clamps (Figs. 6 and 7). Where slippage occurs, the two legs on each side of the knot must be fixed in each respective clamp (Fig. 37) or, unless there are other reasons to the contrary, the overhand knot (Fig. 5) should be used for knot strength tests. This latter is particularly true because the usual hand-tied or machine-made knots are otherwise tested in connection with wet mesh strength and knot stability (see Sections 19 and 20).

The force with which the knots are tightened before the test can affect the result but this effect becomes negligible with the overhand knot. Loosely tied knots are usually weaker and their strength more variable than are tightly tied knots. The time between tying the knot and testing for strength does not affect results significantly so long as it exceeds 24 hours. However, all knots should be tied shortly before the test and should be tightened once more immediately before the test.

For testing, the wet, knotted twine is fastened in the clamps so that the knot is about midway between the clamps. The results of breaks which for some reason do not occur at the knot are disregarded; only results from breaks which occur at the knot are used.

The wet knot breaking strength is reported as the arithmetic mean of all allowable test results, as was the case when reporting wet strength. In addition to this absolute value, the relative knot strength is also reported as a per cent of the wet strength of the unknotted material as follows:

$$\frac{\text{wet knot breaking strength} \times 100}{\text{wet breaking stength (unknotted).}}$$

Calculations for comparing results: If materials of different sizes or weights are to be compared concerning strength efficiency, this can be done by converting strength data to a common basis such as linear density or cross-sectional area. Canada proposes to use the term "specific strength" to identify all such converted data used for comparative purposes. The three following types of converted strength data differ in the units used, but all may be employed directly to compare strengths of different-sized materials.

(a) Breaking length: This figure is the length of the material whose weight at the surface of the earth equals its breaking strength. It is the maximum length of the material which can be supported by one end of itself without that end being broken by the weight of the material. Contrary to common practice, it is better to use this parameter for comparing only materials of the same specific weight.

It is calculated as follows:

$$\text{breaking length (km)} = \frac{\text{breaking load (g)} \times \text{resultant Nm (km/kg)}.}{1{,}000}$$

However, since netting twines are made of several yarns, the resultant Nm has to be estimated from the yarn Nm, and this is difficult because the various hard, medium, and soft twists result in different twist contractions. Thus, the breaking length may be calculated more conveniently as follows:

$$\text{breaking length (km)} = \frac{\text{breaking load (kg)}}{\text{linear density (g/m)}}.$$

To be precise, this calculation can be made only with data, particularly for weight, from tests performed in the standard atmosphere. In a temperate climate, however, tests performed under normal room conditions will be sufficiently accurate for netting materials. The result is rounded off to the nearest whole number.[12]

(b) Unit strength: Another way to compare strengths of different netting twines is to refer the strength to the cross-sectional area of the fibre by calculating the unit strength, kg/mm². Measurement of the actual fibre cross-sectional area can be affected by stretching or swelling the fibre. Thus, the area is estimated from the runnage and the density of fibre and the unit strength may be estimated as follows:

$$\text{unit strength (kg/mm}^2) = \text{breaking length (km)} \times \text{fibre density (g/cm}^3).$$

(c) Tenacity: The tenacity may be calculated as g/den or g/tex. The calculation in g/den is made as follows:

$$\text{tenacity (g/den)} = \frac{\text{breaking strength (g)}}{\text{resultant denier}}.$$

For this formula, the denier figure is normally given for the single yarn, as was the case when calculating the breaking length above. Netting materials, on the other hand, are usually plied twines, as already mentioned. Therefore, the resultant denier of the whole twine must first be determined. This is the weight in grams of 9,000 m of the netting twine. It is easier to compute the tenacity from the breaking length as follows:

$$\text{tenacity (g/den)} = \frac{\text{breaking length (km)}.}{9}$$

Tenacity in g/tex is numerically equal to the breaking length in km.

(2) Extensibility

Extension is the change in dimension of the netting material in the direction of the load, i.e., along the longitudinal axis. It is measured at the same time and on the same machine as strength (see above). For indicating extension the testing machine must be equipped with a suitable autographic device for recording the elongation of the test specimen. The resulting graph shows the amount of extension under the various loads.

Test conditions for extension are the same as those described above for strength. Here, too, tests performed on wet materials are more important than those performed on dry netting materials. For this test, it is essential that the netting twine be placed in the tester under a standard pre-tension, usually equal to the dry weight of a 250-m[13] length of the netting material. As a rule, this weight is sufficient to straighten netting materials which have become kinked or hardened as by preservatives. The pre-tension is applied by hanging appropriate weights from the test specimen. There are even some testing machines on which the pre-tension can be applied directly.

One difficulty in measuring the extension of knotted netting twines is caused by twine coming out of the knot when loose knots are tightened during the test, thereby causing a false extension. Thus, extension tests should be carried out with unknotted materials unless there are particular reasons to the contrary.

Extension at break: The extension at the moment of break is called the breaking extension (total extension, stretch at rupture). At least 10 tests should be carried out and the average calculated. The result is usually reported as a per cent of the initial length:

$$\text{Extension at break (\%)} = \frac{\text{length at break} - \text{initial length}}{\text{initial length}} \times 100.$$

Usually testing machines plot the increase in length directly, and some are even calibrated to give immediately the per cent increase in length for certain initial lengths. For an initial length of 200 mm half the extension in mm is the per cent extension.

Load-elongation curve: In most cases, e.g., if netting is being considered, the extension at break for unknotted twine is of little interest to the fishing industry. In netting, the knots (or the junctions in knotless netting) break at loads lower than do corresponding unknotted twines. This is also true of twines used in other ways, e.g., for fishing lines. Thus, for the manufacture and use of netting materials, it is important to know extensions at loads lower than the breaking load.

The extension under different loads is plotted in the so-called load-elongation curve, with the extension on the abscissa and the load on the ordinate (Fig. 8a). Where this graph is not drawn by an automatic recorder, it may be plotted if two persons read off the load and extension at the same time during the test. It is not advisable for one person to do this by stopping the tester periodically to measure the load and extension, because

[12] Where tests are performed in the standard atmosphere, results may be reported to the second decimal place.

[13] The amount of pre-tension is variously specified. The 250-m weight agrees with most standards. The international BISFA specifies the 500-m weight for filament yarns. The measurement of the meter-weight is described in Section 5.

some stress relaxation at constant extension occurs. If single values of extension are to be reported, these should be at 1/20, 1/10, 1/5, 1/4, 1/2, and 3/4 per cent and at the full breaking load. Usually it is better to read off extensions under low loads at small, regular intervals, and extensions under higher loads at greater intervals, e.g., of load in kg. Five tests should be conducted.

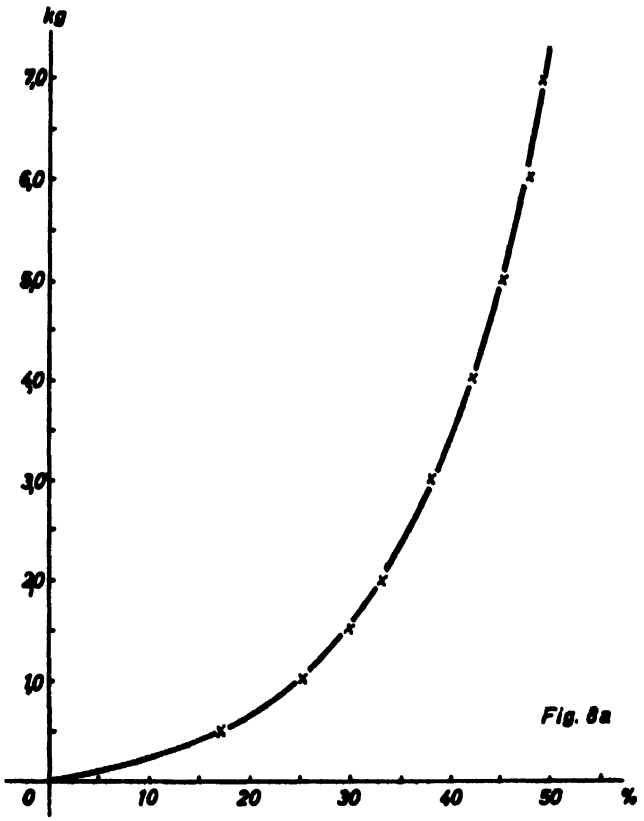


Fig. 8a

In order to compare the extensibilities of netting materials of different breaking strengths, the extension values are not plotted against the absolute load in kg but, usually, against the per cent of the breaking load, as shown in Fig. 8b for netting materials made of different man-made fibres. Another procedure is to plot the extension against a specific load such as g/den, km-weight, or g/tex. Because strength is more variable than (and hence cannot be measured so accurately as) twine weight, the latter procedure is often the more precise.

Elasticity: Under stress, netting materials are extended by an amount called "total elongation". When the stress is removed, this extension may decrease totally or in part. This ability to recover extension is called "elasticity". If, after the stress is removed, the extension does not decrease completely, the remaining extension is called "permanent" or "irreversible elongation". The extension which decreases when the stress is removed is called "elastic elongation". With most netting materials, part of the elastic or reversible extension decreases as soon as the stress is removed and part decreases only

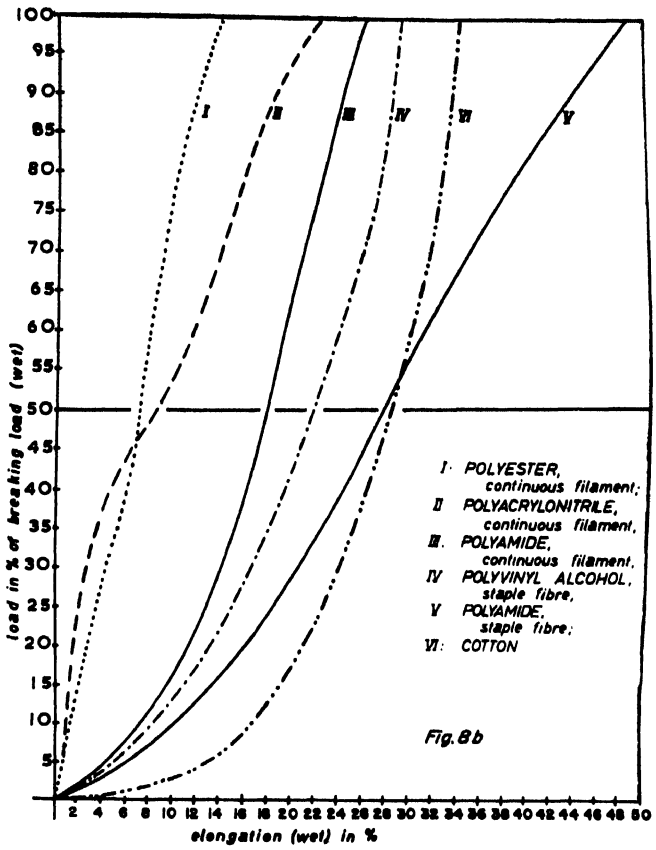


Fig. 8b

after a period of time. That part of the elastic extension which decreases at once is called "immediate elasticity" and that which decreases slowly after removal of the stress is called "delayed elasticity". Thus, "total elongation" consists of three parts, viz. "immediate elasticity", "delayed elasticity", and "irreversible elongation", and all three parts should be considered when studying elasticity.

Elasticity is important in some fishing gear, particularly that from which fish can escape by slipping through the meshes or in which the fish are caught by their heads (e.g., gillnets). Further, elasticity is important to minimise the effect of sudden, jerking stresses (e.g., cyclic shock loads).

The test procedure for measuring elastic extension in textiles has not yet been standardised. It is usually done on strength testers, as described before, by stressing and relaxing the test specimens on a definite cycle.[14]

For the fishery, several proposals for testing elasticity have been advanced, but not yet compared. The tests are conducted with wet, unknotted, netting material.

Proposal (a):[15] Specimens of netting twine (wet or dry) from the same sample are fastened successively in the strength tester with 200 mm test length under the 500-m weight pre-tension. Each specimen is stressed in turn by the machine to either 10, 20, 30, 40, 60, or

[14] See DIN proposal 53835, ASTM Designation 1333-54T, or the Japanese proposal in Modern Fishing Gear of the World, p. 66, items 5-11.

[15] Institut für Hochseefischerei, Rostock-Marienehe, according to DIN 53835.

80 per cent of the average breaking load for 10 min. Then the load is removed for 15 min. For quick tests for comparative purposes, one test to 50 per cent of the breaking load is sufficient.

On the strength tester, the extension is read as soon as the desired stress has been applied. The stress is then maintained for the 10 min, by continually adjusting the stress on the testing machine to the desired value, while the extension of the twine increases further to a constant value.

Then, the stress is reduced to the pre-tension value, and the immediate change in length for the appropriate degree of stress is recorded. To do this, the initial 200-mm test length is marked on the material and the lower clamp is loosened so that only the pre-tension affects the specimen. By moving the lower clamp to the mark, the remaining extension can easily be read. The test specimen is then removed from the tester and immersed in water without stress for 15 min after which the final extension is measured under the above pre-tension.

Each test to each degree of stress has to be carried out with a new specimen.

According to DIN 53835, the test has to be repeated for each load until constant values are obtained. At least five tests have to be conducted at each load.

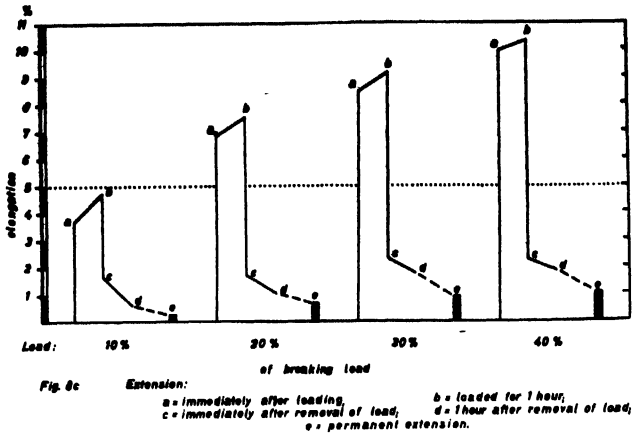


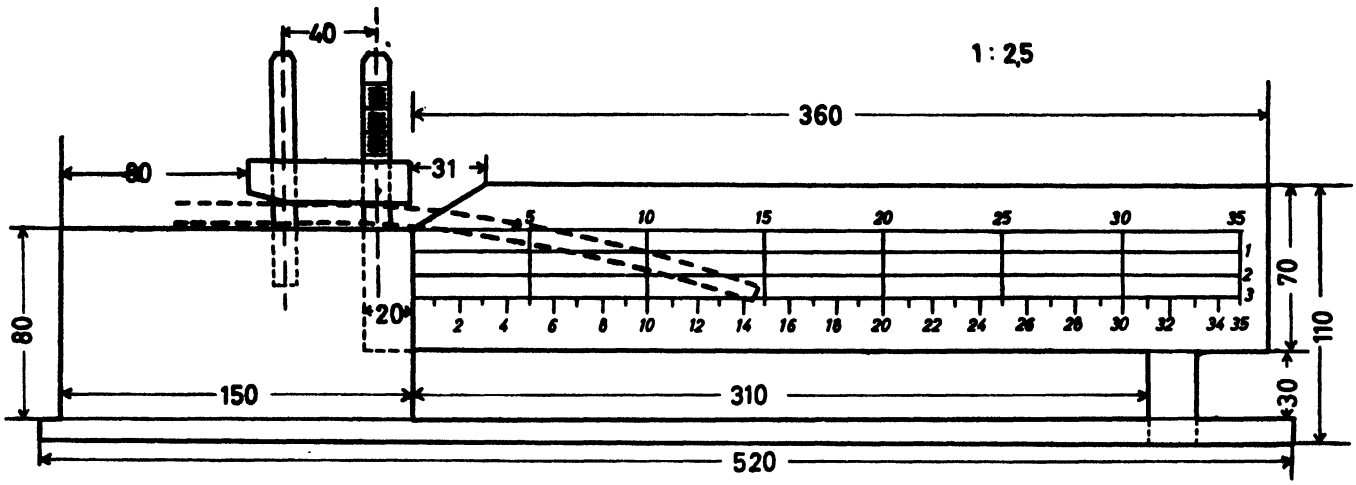
Fig. 8c

Proposal (b):[16] For the test, a 50-cm length is marked on a 1-m piece of the netting material under 250-m weight pre-tension.

The material is stressed to 30 per cent of its average breaking strength for one hour, then the marked length is measured. From this measurement, the total elongation at this load is calculated.

Then the load is reduced to the above pre-tension and the marked part is measured once more. All the while, the specimen is kept wet by spraying it with distilled water. After each pair of measurements, at test load and at pre-tension, the specimen is soaked in water. These measurements are repeated periodically with the same specimen until the readings are constant. Some materials require several days to reach equilibrium. The final length under pre-tension gives the permanent extension. Elastic extension may be computed as the difference between the final total extension under the test load and the permanent extension. As mentioned, elasticity may be computed as the ratio of elastic extension to total extension.

The test load, equal to 30 per cent of the breaking strength, was chosen arbitrarily. There may be advantage in carrying out this test to other degrees of stress. Fig. 8c demonstrates the method of data presentation



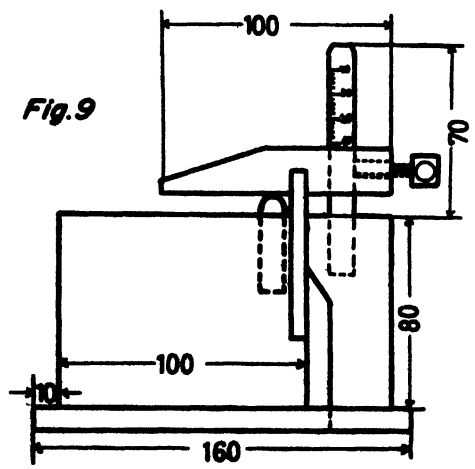


Fig. 9

[16] Institut für Netzforschung, Hamburg.

and gives results of extension and elasticity tests on 'Perlon' continuous-filament trawl twines at stresses equal to 10, 20, 30 and 40 per cent of the average breaking strength.

(3) Flexural stiffness

The term flexural stiffness refers to the resistance of the netting twine to lateral or bending deformation. More specifically, it may be defined as the force required to cause a unit of bending deflection. By this definition, when a fish touches a net, flexural stiffness is a measure of the degree to which the netting itself resists the movement of the fish. Thus, any method for measuring flexural stiffness should assess the force which causes the deflection. As defined here, flexural stiffness depends primarily on the elastic modulus of the twine (governed by fibre stiffness and twine construction), on the distance between the point of support and the point at which the force is applied, and on the diameter of the twine. This last is a very important factor. The stiffness of the netting material is reported to affect the efficiency of many types of fishing gear. Usually, low stiffness increases catching efficiency whereas high stiffness makes the nets easier to handle. Sometimes the antonym "flexibility" is used as the characteristic of netting materials, as, for example, when the term "softness" is used to characterise the desired low resistance to deformation of soft-laid materials.

Different workers, working with different materials, have recommended widely differing procedures for measuring the stiffness of netting twines. Theoretically this property may be measured according to either of two basic principles: either the force which causes a certain deflection (proposals (b) and (c)) or the energy associated with this force (proposal (d)) is measured, or deflection of a horizontally mounted specimen under its own or an added weight (proposal (a)) is measured. This last procedure is widely used for testing textile fabrics and paper.[17]

Proposal (a):[18] The flexural stiffness is measured by fastening the specimen by one end only in the holding device (Fig. 9).

The wet specimen is slipped horizontally under the vertically adjustable upper jaw of the clamp in such a way that it does not touch that jaw. The leading end of the specimen approaches a horizontal reference line, 3 cm below the face of the clamp, at a point nearer to or farther from the clamp according to the linear density and flexibility of the specimen. The specimen is advanced until it touches the graduated reference line, and the horizontal distance of the point of contact from the jaw is read directly as the measure of stiffness.

Five specimens of each material are each tested 10 times. The average gives a figure for stiffness which is greater for stiffer materials.

[17] Further proposals for measuring the flexibility of netting materials, particularly in meshes, are presented in Roessingh, M.: Recent experiments on gear and mesh selection in the Netherlands. ICES-CM-1959, No. 88.

[18] Institut für Hochseefischerei, Rostock-Marienehe.

Care must be taken that the netting material has no initial deformation which would cause errors. Such errors are particularly possible with wet netting twines of medium count.

Fibres of different specific weights cannot be compared by this procedure because the twine is deflected by its own weight. The same is true of twines treated with preservatives of different weight, even though the twines may be of the same number.

Proposal (b): [19] The principle of this procedure is to measure the force required to deform the netting material (cf. the force required for a fish to pass through the mesh).

Fig. 10 shows the required apparatus.

[19] Institut für Netzforschung, Hamburg: Lötzener Methode v. Brandt, A.: Arbeitsmethoden der Netzforschung, Stuttgart, 1947, pp. 44-49.

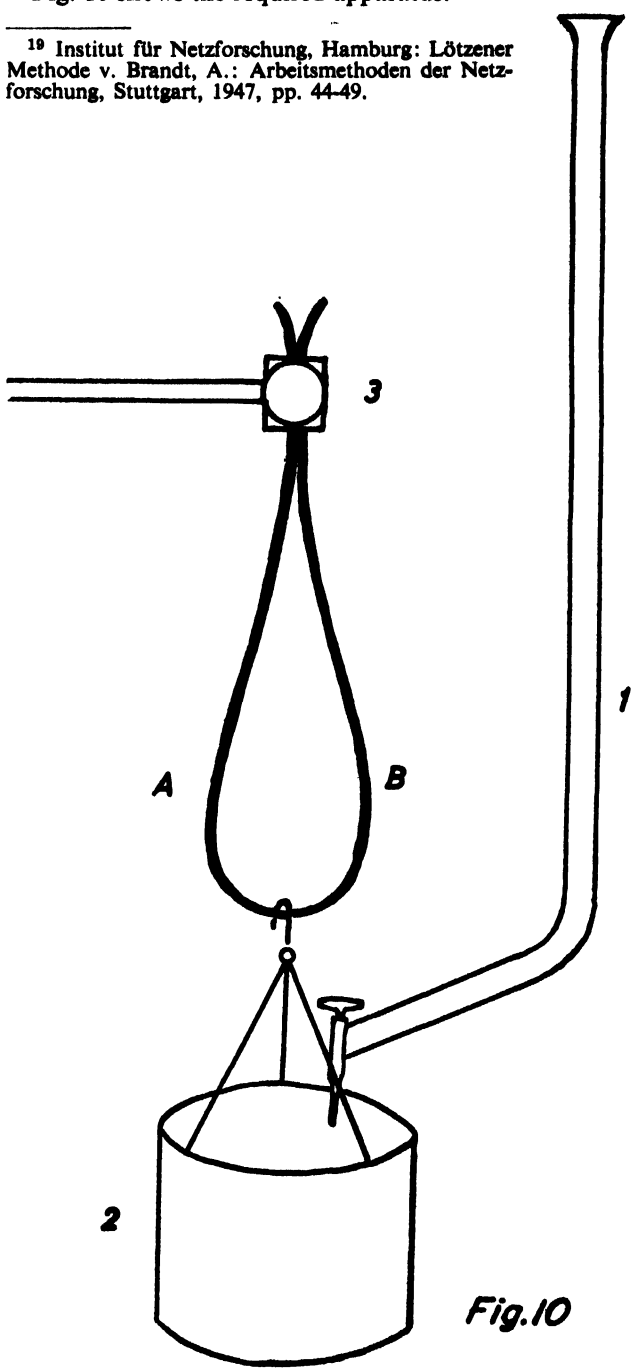


Fig.10

Twenty cm (8 in) of the specimen are bent in such a way that they form a loop (Fig. 10, A-B) and the ends are fixed in the metal clamp (Fig. 10, 3). The stiffer the material the wider the loop will be. A light 'Cellophane' vessel (Fig. 10, 2) of about 3 gm weight and 50 cc capacity, is hung from the loop. Care must be taken that the vessel is suspended from the bottom of the loop. Water is fed into the vessel from a burette, preferably automatically filled, adjusted in such a way that the flow is by steady drops rather than by a continuous jet (about 40 cc/min). The flow of water gradually draws the loop together. The opening of the loop at its widest point (A-B) is constantly observed with the assistance of a gauge and the flow of water is stopped as soon as the opening has decreased to 5 mm. The weight of the vessel and the quantity of water which has dropped into it, as read from the burette to the nearest cc, is used as the measure in grams for the stiffness of the material being tested. Here 1 cc of water is taken to weigh 1 g. The test should be repeated 10 times for a good average.

It is desirable to use the same vessel for all weights of material, but it may be necessary to use smaller vessels for softer materials and larger vessels for harder materials.

For comparing different preservatives and the stiffening caused by the treatment, the following classification is used:

up to 2 gm = extremely soft
3-10 gm = very soft
11-15 gm = soft
16-25 gm = medium hard
26-50 gm = hard
more than 50 gm = wire-like.

Special variations of the procedure have been proposed for particularly soft net materials and for small samples.

Because a vessel must be used to contain the water, a certain initial weight cannot be avoided. Thus, if the specimens are very soft, measurement may be impossible because the loop opening is drawn together to less than 5 mm by the weight of the vessel alone. The weight of the vessel may be counterbalanced by the arrangement shown in Fig. 11. [20] In this, one pan of the balance is the vessel into which the water is allowed to flow, and its weight is off-set by the weight of the other pan. A little glass hook is hung into the loop of twine and is attached to the balance by a fine strand ('Perlon' or nylon). The initial stress on the loop can be decreased to 0·1 gm in this way. Water flow is regulated to about 5 cc in 60-100 sec by a burette with a very small opening, thus permitting easier regulation for softer materials. With this modification, results can be reported to the nearest 0·1 gm. Otherwise, the procedure is the same as described above.

But even with this modification, it is possible that extremely soft materials cannot be tested because the loops formed with 20 cm of the material close under their own weight to less than 5 mm loop-opening width.

[20] According to an unpublished proposal by E. Schoeninger.

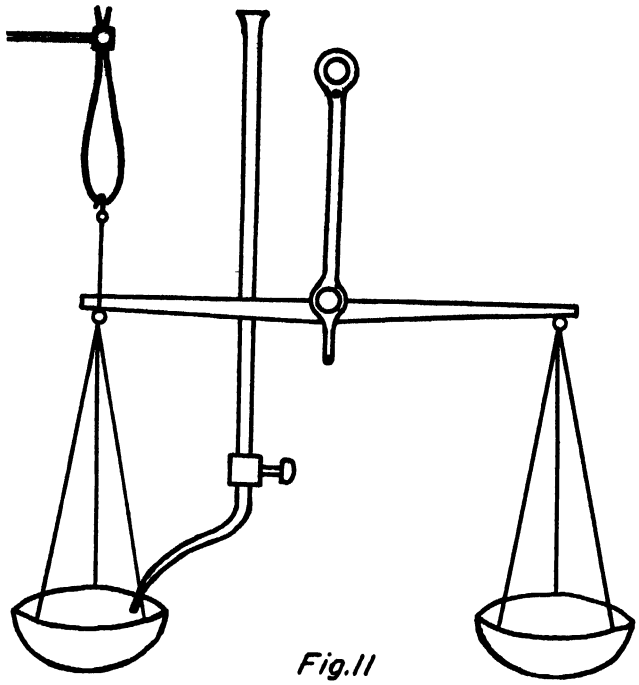


Fig.11

Proposal (c): [21] Twenty turns of the material are wound close to each other around a rod 4 cm in diameter and are held together by a narrow strip of adhesive tape. This coil is removed from the rod and its diameter is reduced from its initial value of about 4 cm to 2·5 cm (1 in) by an increasing diametrical load.[22]

Two flat plates about 10 cm in diameter are fitted to the clamps of an electronic dynamometer. The moving clamp is lowered a few centimetres and the cord cylinder is placed on the lower flat plate (Fig. 12). The lower clamp is then moved upwards until the cylinder becomes an ellipse with a short axis of 2·5 cm. The force required for this is taken as the measure of flexural stiffness.

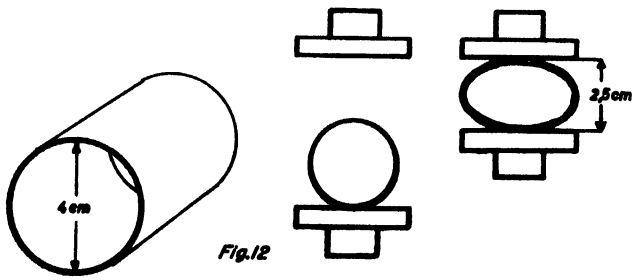


Fig.12

Proposal (d): [23] For measuring the flexural stiffness of coarser netting materials (and cordage) the specimen is suspended with a weight at one end like a pendulum and is allowed to swing. Stiffer materials resist the swing more strongly and stop the swinging sooner.

[21] van Wijngaarden, J.K.: Methods of testing net cords and nets especially made of synthetic material. Rayon Revue 11, pp. 146-160, 1957.

[22] This testing technique is similar to those used in the textile industry for cloth.

[23] Taylor, H. F. and Wells, A. W.: Properties and values of certain fish-net preservatives. Doc. No. 947, U.S. Bureau of Fisheries, Washington, D.C., 1923.

A wet specimen 30-cm (1 ft) long is attached to a clamp and is stressed by a 50-g[24] weight (Fig. 13a). The wooden base is sawn to form a sector of a circle of 30-cm radius and is placed 30 cm from the clamp. The pendulum is raised along the sector for a distance of 15 cm (6 in) and is released without acceleration. The number of swings for the amplitude to decrease to half its original value are counted as the measure of stiffness.

The test is repeated 10 times with each of 10 samples. If the sample becomes unduly softened at the clamps by the test, the number of swings may be reduced by a stopping device as shown in Fig. 13b.

If fine, twisted netting materials are being tested, care must be taken that the twine does not lose twist. If it does, the pendulum will not swing always in the same plane and the number of swings to half amplitude cannot be counted.

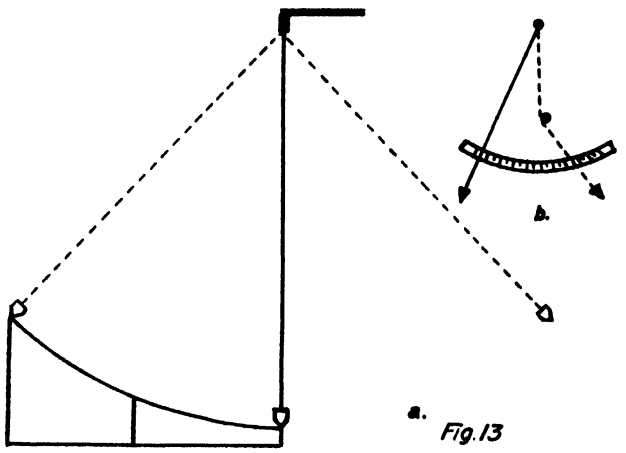


Fig. 13

(4) Abrasion resistance

The term "abrasion resistance" refers to the ability of the material to withstand abrasion under defined, conventional conditions. It is said to correspond to the mechanical wearing out with use. But it is difficult to simulate in the laboratory the conditions which are experienced by fishing gear materials during fishing. It is not possible to obtain absolute values from test procedures because actual mechanical wear is a complex process. The original nature of the material and subsequent damage by light or micro-organisms can affect abrasion resistance. Also, the results of abrasion tests are affected by the type of testing machines.

There are two ways in which abrasion can occur in fishing gear:

(a) The netting materials may be abraded against other harder objects such as the sea floor or the hull of the boat.

(b) The netting materials may be abraded against one another as, for example, in the knots or in the seams of the net.

In textile-abrasion tests, the specimens may be rubbed until they break or otherwise may be rubbed for a certain period, then the change in other properties such as strength studied.

Abrasion against hard objects: Abrasion of netting materials against comparatively hard objects is usually regarded as the more significant procedure. For this, a special testing machine is used in which the test specimen is stressed and is rubbed on or by a hard object. The number of rubs required for a given amount of wear decreases as the load is increased. Fig. 14a represents the Sander test machine,[25] while Fig. 14b represents a design reported by Shimozaki.[26] Both testing machines work according to the same principle and the specimens are kept constantly wet during the test, but the angle described by the netting material at the point of contact with the abradant is different on the two machines. In the Sander testing machine, the specimen assumes an angle of about 90° at the abradant as shown in Fig. 14a, but, in the design reported by Shimozaki, the corresponding angle is about 150°. In the Sander testing machine the specimen is pulled back and forth, whereas in the design reported by Shimozaki, the specimen is held fast while the abradant is moved back and forth.[27]

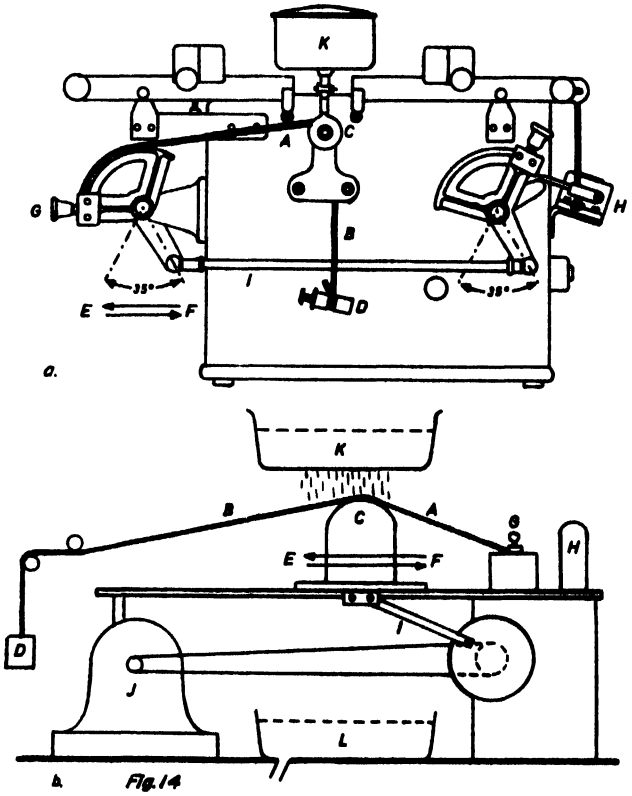


Fig. 14

[24] It would be more suitable to use the 250-m weight.

[25] Klust, G.: Untersuchungen über die Scheuerfestigkeit von Fischnetzschnüren. Protokolle zür Fischereitechnik 3, pp. 64-88, 1954. This machine was originally developed for testing textile fabrics, not netting materials.

[26] Shimozaki, Y.: Characteristics of synthetic twines used for fishing nets and ropes in Japan. Modern Fishing Gear of the World, pp. 19-29, 1959.

[27] The Institut für Hochseefischerei in Rostock-Marienehe uses an abrasion testing machine designed by Bobeth-Hahn (DRP No. 8961). On it, the load on the specimen may be held constant or it may be changed between maximum and minimum values at every complete rubbing cycle.

The water pouring steadily over the specimen serves not only to keep the specimen wet but also to keep it cool and to wash away loose particles as they are rubbed off the material.

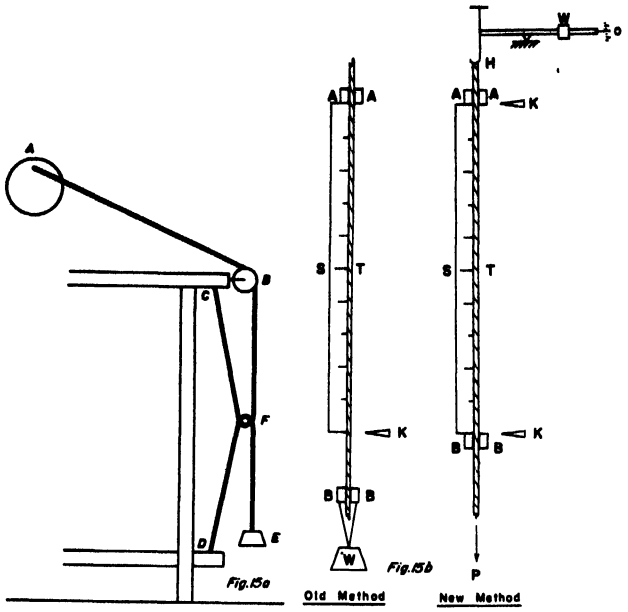
The netting twines are mounted as shown in the drawings.[28] Several specimens may be mounted beside one another. Loads are attached to the free ends of the netting material, equal to or greater than the 250-m weight according to the purpose of the test.

On the Sander machine, the test specimen is pulled back and forth over a corundum rod in which particles of corundum are bound in a ceramic material. The size of the corundum particles is standardised, is chosen according to the material under test, and must always be reported. The machine described by Shimozaki used oil stones for the abradant. The Sander machine imposes 63 rubbing cycles per minute, whereas the machine described by Shimozaki imposes 80, and these cycles are counted automatically on both machines. On the Sander machine the stroke amplitude, E-F, is 6 cm (2⅜ in) if the machine is set up as shown in Fig. 14a. The specimen is rubbed until it is completely worn and breaks. The test is repeated at least 25 times with each sample, and the arithmetic mean of the results is taken as the abrasion resistance.

The type of abradant, the magnitude of the load on the specimen, the speed of rubbing, the angle described by the specimen at the abradant, and the length of the rubbing stroke all affect the result and should be included in the report.

Abrasion against itself: For testing abrasion resistance between similar or different netting twines an apparatus was proposed by Taylor and Wells.[29] As can be seen in the diagram (Fig. 15a), the two twines A-B-F-C and D-F-E are rubbed against one another. The first twine is fastened eccentrically to disc A, is led over the small roll B, through the loop in the second twine at F, and is attached to the table at point C. The second twine is fastened to the table at point D and is led through the loop of the first twine at point F. The free end of the second twine is stressed by the weight E.[30]

The weight should be between a fifth and a twentieth of the average breaking strength of the specimen and should be chosen so that between 100 and 200 complete rubbing cycles are required before the specimen breaks. Taylor and Wells recommend that 50 tests be averaged for each result. The load, the speed of rubbing, and the angles of contact should be reported with each result.



(5) Weight

Accurate tests for material weight, as required for the calculation of breaking length, can be conducted only in a standard atmosphere which complies with official international standards for temperature and relative humidity (see above). In addition to tests for twine count which are not within the terms of reference for these discussions, the weight of the netting materials in these standard atmospheric conditions is of interest for comparison with the wet weight. Also, the weight of the netting material in water is important.[31]

Dry weight: The old Canadian procedure,[32] as shown in Fig. 15b, is to fasten the specimen of netting twine, T, in a clamp, A-A, by its upper end, allowing it to hang vertically (not horizontally as shown in Fig. 20 and Fig. 21). The required pre-tensioning weight, W, is hung from the lower end of the specimen by means of the clamp B-B. This vertical arrangement avoids the effect of friction in pulleys, etc. The specimen is cut first, while under appropriate pre-tension, against the scale S, at a point one m below the upper clamp as shown at K, and is then cut a second time at the lower face of the upper clamp, A-A. Ten such 1-m specimens are weighed together and the linear density or runnage of the netting material is computed.

A refinement of this apparatus is shown as the new method in Fig. 15b. It consists essentially of two clamps, A-A and B-B, mounted on a vertical support. A steel meter-scale, S, divided to the nearest 0·5 mm, is mounted behind the clamps so that the distance between the clamps may be set accurately. A trip balance for pre-tensioning the specimen is mounted above the upper

[28] A-B = netting material under test, C = abradant, D = weight, E-F = direction of reciprocating motion, G = clamp for test specimen, H = cycle counter, I = crank, J = motor, K = water tank supplying water to specimen, L = water tank catching water from specimen.

[29] Taylor, A. F. and Wells, A. H.: Properties and values of certain fish-net preservatives. Document 947, U.S. Bureau of Fisheries, 1923.

[30] It is important to keep the angles of the abrading materials equal for all comparative tests.

[31] See Chapter 21: Weight of netting.

[32] Carrothers, P. J. G.: Fisheries Research Board of Canada, St. Andrews, N.B.

clamp, A-A. The upper end of the specimen is fastened to the hook, H, under the pan of the balance and the specimen is allowed to hang between the open jaws of the clamps. The weights, W, on the balance beam are set to exert a pre-tensioning force on the netting material equal to the 500-m weight and the clamps are set so that their facing edges are exactly 1 m apart. The lower end of the specimen is pulled by hand as shown at P until the balance pointed reads "O" on the balance scale, and the jaws of the clamp B-B are tightened. The jaws of clamp A-A are then tightened. The specimen is cut at the facing edges of both jaws as shown at K-K and the 1-m piece is removed for weighing. As before, 10 such 1-m pieces of the netting material are weighed together and the runnage (m/g) or the linear density (g/km) can easily be calculated.

Wet weight: For measuring the wet weight of netting twines out of water, the test specimens are cut as described and soaked. The resulting shrinkage is not considered because the greatest interest lies in how much more the specimen weighs wet than dry.

When the netting material has become completely soaked, it is removed from the water, allowed to drain, and is weighed.[33] The wet weight is reported as a per cent of the dry weight according to the formula:

$$\text{Wet weight (\%)} = \frac{\text{wet weight (g)} \times 100}{\text{dry weight (g)}}$$

or as the per cent increase in weight according to the formula:

$$\text{Water absorption (\%)} = \frac{\text{wet weight—dry weight}}{\text{dry weight}} \times 100.$$

Weight in water: The weight of netting materials as well as of netting in water depends not only on the specific gravity of the fibre but also on the speed with which water soaks into the material and on the tendency for air bubbles to remain in or on the material. Because of this air entrainment, quite dense materials can float at or near the surface of the water unless they are loaded to cause complete immersion.

The apparatus shown in Fig. 16 may be used to measure the weight in water.[34] A specimen of netting twine of known weight (e.g., 15 g) is completely soaked as described above and is fastened to the bottom of the balance pan as shown in Fig. 16. It is suspended in water (distilled, fresh, or sea) at about 20°C (68°F). As distilled water contains no dissolved air, the formation of bubbles on the specimen may be minimised by its use. The weight of the specimen under these conditions is measured and is reported as a per cent of the weight of the air-dry specimen.

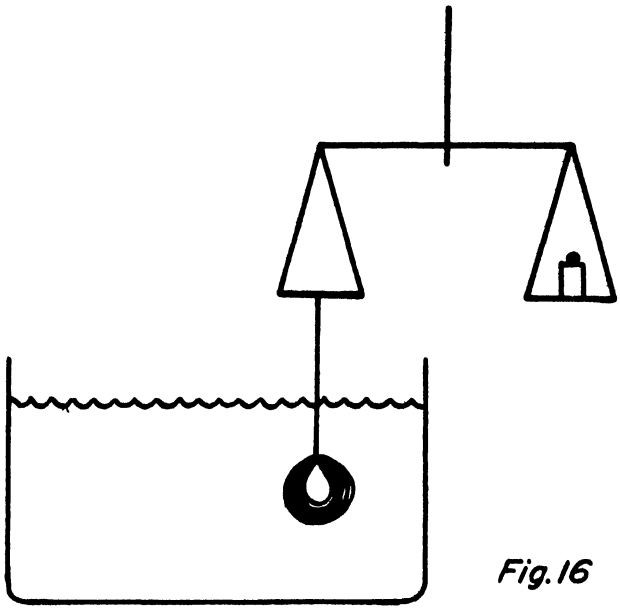


Fig. 16

$$\text{Weight in water (\%)} = \frac{\text{weight in water (g)} \times 100}{\text{air-dry weight (g)}}.$$

It is also possible to compute the weight in sea water from the formula:[35 36]

$$\text{Weight (\%) in sea water} = \left(1 - \frac{\text{specific gravity of sea water}}{\text{specific gravity of material}}\right) \times 100.$$

Similarly, the specific gravity of the fibres may be computed from the following formula:

$$\text{Specific gravity} = \frac{0{\cdot}998}{1 - \frac{\text{weight in distilled water}}{\text{air-dry weight in air.}}}$$

Floating ability and sinking speed: Of particular interest with netting twines and still more important with certain complete nets, is the time for which they remain buoyant, i.e., whether they float for a longer or shorter time or whether they sink quickly. Whether the ability to float for a long time (e.g., netting materials made of fibres having specific gravity less than one) or the ability to sink quickly is important depends on the type of fishing gear. Different procedures for measuring this property have been developed for different reasons.

Proposal (a), Floating ability:[37] The ability of a specimen to retain its lightness in water can be measured on the same apparatus as was used for measuring the weight in water.

The specimen of netting material is suspended in a vessel which is filled with fresh water or sea water.

[33] In Modern Fishing Gear of the World, p. 21, Shimozaki gives factors for the estimation of the dry weight (linear density—mg/m) and the wet weight of several man-made and cotton netting materials.

[34] v. Brandt, A.: Arbeitsmethoden der Netzforschung, Stuttgart, 1947, pp. 107-108.

[35] Carrothers, P. J. G.: The physical properties of netting and twines suitable for use in commercial fishing gear. Modern Fishing Gear of the World, pp. 69-74, 1959.

[36] In Modern Fishing Gear of the World, p. 22, Shimozaki gives factors for estimating the weight in water from the dry weight for materials made of several man-made fibres and of cotton.

[37] v. Brandt, A.: Arbeitsmethoden der Netzforschung, Stuttgart, pp. 107-108, 1947.

Weights are placed on the specimen to hold it below the surface of the water. At intervals of time, first of hours and later of days, the added weights are removed and the weight of the specimen alone in the water is measured. This procedure is repeated over a period of time until the weight in water remains constant.

The weight in water may be reported as a per cent of the weight of the air-dry specimen as described above. For better understanding, the changes in floating ability may be plotted graphically. The time in hours or days is plotted against the abscissa and the increase of weight in water, expressed as a per cent of the dry weight, is plotted against the ordinate. Fig. 17 shows three cotton twines prepared by different methods. According to the preparation the floating ability will be lost immediately (I and II) or after some hours (III).

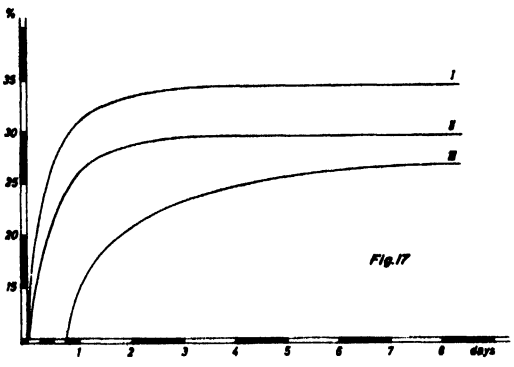


Fig. 17

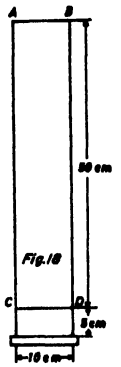


Fig. 18

Proposal (b), Sinking speed:[38] For determining sinking speed, a piece of netting twine 2-cm ($\frac{25}{64}$ in) long is knotted in the middle and is soaked in clear water for 12 hours. A glass vessel is filled to a height of 50 cm with water at 20 ± 5°C (Fig. 18) and the test specimen is allowed to fall from the surface of the water. The time required for the sample to fall the distance of 50 cm is measured in seconds and the average sinking speed is calculated in cm per sec. Three tests should be performed with each specimen. Results from tests in which the sample sinks at an angle or close to the wall of the vessel should be rejected.

(6) Diameter

For measuring diameter, generally speaking, special thickness gauges of different types are used. With these a certain diametrical pressure on the netting material cannot be avoided so that the results of measurements on soft-laid or loosely braided materials or on those made of staple fibres are too small.[39] Therefore, it has been proposed to test these materials according to an ASTM procedure (proposal (b)). The facts that the diameter of netting twine is decreased as a result of extension under tensile load and that the cross-section of the twine may be elliptical or even rectangular rather than circular must be taken into consideration.

Proposal (a), for measurement of monofilaments and firm netting twines: A manual thickness gauge[40] (Fig. 19a) may be used for this measurement. The test specimen is placed between the two circular pressure feet (A_1-A_2 in Fig. 19a) which are completely flat and are set parallel to one another. The feet separate to 10 mm ($\frac{13}{32}$ in) apart without pressure so that all kinds of netting materials and even thinner cordage used in the fishing industry can be measured. By pressing lightly on the key (B in Fig. 19a) the thickness of the material may be read directly from the scale (C in Fig. 19a) to the nearest 1/100 mm. The results of at least 20 measurements should be averaged, and with very irregular materials even more measurements may have to be made. As mentioned, it must be noted whether or not the specimens really have a circular cross-section.

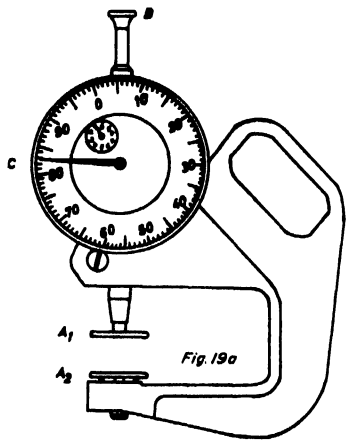


Fig. 19a

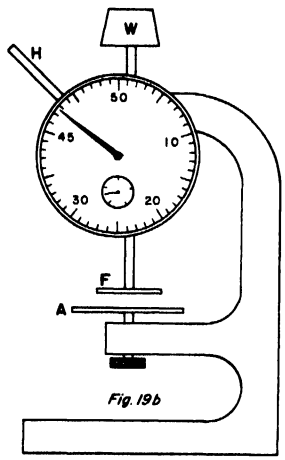


Fig. 19b

Alternatively, a dead-weight dial gauge[41] (Fig. 19b) may be used for this measurement. In this, four lengths of the specimen are laid parallel on the plane anvil, A, and the movable foot, F, which is plane and parallel to the anvil, is lowered gently onto the specimen by means of the handle, H. The weight, W, is chosen so that the foot exerts a standard total force of 6 oz (170 g) on the specimen. The thickness of the specimen is read to the nearest 1/1,000 in directly from the dial.

Proposal (b): Particularly for soft, compressible netting materials. Canada has suggested that ASTM Designation D578-61 for glass yarns be used for measuring the diameter of netting materials. This specification reads:

"(a) This method is based upon the use of a microscope equipped with either a micrometer eye-piece with a movable scale or a filar micrometer eye-piece.

(b) Apparatus. A microscope having a movable stage which can be rotated to bring the yarn parallel

[38] Japan Chemical Fibres Association. The manufacture and testing of synthetic yarns and fibres used in Japanese fishing gear. Modern Fishing Gear of the World, p. 68.

[39] Carrothers, P. J. G.: The physical properties of netting and twine suitable for use in commercial fishing gear. Modern Fishing Gear of the World, pp. 69-74, 1959.

[40] Klust, G.: Veränderung des Durchmessers in Netzganen durch Wässerung. Protokolle zur Fischereitechnik IV, pp. 84-106, 1956.

[41] ASTM Designations D204-57T and D885-62T, CGSB Schedule 4-GP-2, Method 37, and B.S. 2544: 1954.

to the cross hair shall be used. The magnification shall be of such power that the yarn shall cover approximately one-quarter of the field of view.

(c) Procedure. Mount the yarn on the movable stage of the microscope by means of a yarn carrier which is provided with suitable guides to maintain a constant tension. Take care that no change in twist occurs in mounting the yarn. Rotate the stage until the yarn is parallel to the cross hair. Determine the diameter of the yarn as the difference in the micrometer settings when the cross hair is moved from one edge of the yarn to the other.

(d) Number of measurements. Make 20 measurements at least 1 ft apart, and take the average as the diameter of the yarn."

The Fisheries Research Board of Canada has found a projection microscope to be just as accurate as, and more convenient to use than, the movable stage micrometer eye-piece instrument described above. First, the image of a stage micrometer is projected by the microscope on the screen on the bench and an appropriate scale and vernier for the screen, reading to the nearest 0·01 mm at the stage, is prepared from the image. The netting material is then mounted on the stage of the projection microscope, as described above by ASTM, and its diameter is read directly by adjusting the specially prepared scale and vernier to the image of the material on the screen. As in the ASTM designation, 20 measurements should be made. An F = 32 mm Macro-Tessar lens has been found suitable for most materials.

Besides avoiding compression of the material, these optical procedures permit study of the profile of the material for irregularities and fuzziness, and may be adapted to studying diameters of the material in water and with different tensile loads on the material.

Proposal (c): Coilwinding method.[42] Twenty turns of the netting material are wound closely and parallel to one another around a cylinder of about 5 cm diameter. The overall width of the 20 turns is measured with callipers and is divided by 20. The result is reported as the thickness of the material in mm. Five tests should be performed. The difficulty is that uneven tension in the specimen and variations in the angle at which the material is fed on to the rod can affect the result.[43]

(7) Surface roughness

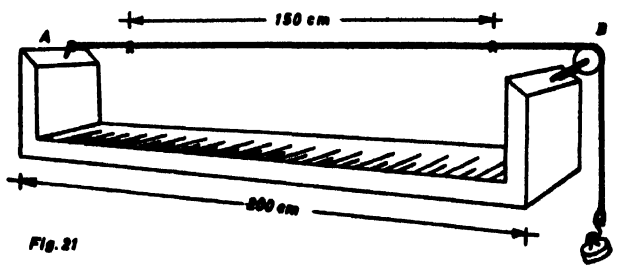
Even if there is little danger of the netting material becoming compressed during the measurement of diameter, there is still the possibility that netting materials made of staple fibres will be much thicker in water as a result of protruding fibres than is indicated by the measurements described in Section 6.[44] This surface roughness also affects several other properties, such as knot stability (see Section 20), pollution of nets (see Section 22), hydrodynamic drag, and selectivity of catch. So far, however, a procedure for measuring surface roughness has not been developed and, until now, tests have been restricted to visual observations, such as by photographs.[45]

(8) Shrinking and lengthening

Generally speaking, the length of netting materials changes when they are soaked in water. Usually a shrinkage occurs, but sometimes a lengthening takes place. Of greatest importance is the fact that this change in length affects the size of the mesh (see Section 18). These length changes may be determined either on the unknotted material or by measuring the size of mesh. However, the two results are generally not in agreement because of the effect of the knots, quite apart from the effect of any difference between the measuring procedures. The main source of the difference in results lies in the fact that shrinkage in the netting material is usually measured under a pre-tension which is graduated according to the linear density of the material, whereas the mesh size is measured either without pre-tension or with a pre-tension which has been agreed upon by international conventions but which is not related to the runnage of the material.

Tests for length change may be conducted to determine the effect of cold tap water or they may be conducted to determine the effect of higher temperature, e.g., by boiling during dyeing or hot treatment with a preservative. The test procedures which have been proposed for the fishing industry to date do not differ significantly from one another.

Proposal (a):[46] For measuring length, the specimens are mounted in the apparatus as shown in Fig. 21. To avoid errors resulting from pulley friction, scale parallax, and twine sag, it has been recommended that the apparatus of Fig. 21 be mounted vertically and that the test specimen be hung very near to the scale. The specimen, more than 2 m long, is attached to point A (Fig. 21) and is led over the roll B, 200 cm away. A load equal to the 250-m weight[47] is applied to the free end.



[42] Japan Chemical Fibres Association. The manufacture and testing of synthetic yarns and fibres used in Japanese fishing gear. Modern Fishing Gear of the World, p. 65.

[43] Hamilton, J. B.: Direct method for measuring yarn diameters and bulk densities under conditions of thread flattening. The Journal of the Textile Institute, Transactions, 50, pp. T655-672, 1959.

[44] Carrothers, P. J. G.: The physical properties of netting and twines suitable for use in commercial fishing gear. Modern Fishing Gear of the World, pp. 69-74, 1959.

[45] v. Brandt, A.: Zur Knotenkonstanz von Fischnetzen. Archiv. für Fischereiwissenschaft 9, pp. 244-265, 1958.

[46] Klust, G.: Längenveränderung von Netzgarnen, Protokolle zur Fischereitechnik VI, pp. 70-83, 1956.

[47] BISFA rules for synthetic fibres specify a pre-tension equal to the 500-m weight.

For determining changes in length due to wetting, two or more points are marked on the dry, pre-tensioned specimen before it is soaked, and the distance between these points is measured. The specimen is soaked for at least 12 hours in fresh or sea water at normal temperatures. Otherwise, the specimen may be boiled or treated in any other way as by preservatives or by dyeing. Then the distance between the marked points is measured once more in the manner described above.

The final length is reported as a per cent of the initial by length:

$$\text{Final length (\%)} = \frac{\text{Final length (cm)} \times 100}{\text{Initial length (cm)}}.$$

Proposal (b):[48] Five knots are tied in a piece of netting twine at intervals of about 1 m and each part of the material, as defined by the knots, is mounted in turn on the measuring board as shown in Fig. 20. As mentioned for Proposal (a) above, the apparatus would preferably be mounted vertically. The specimen is stressed by a standard pre-tension and the distance between each pair of successive knots is measured to the nearest 1 mm. The sample is then placed, unstressed, in cold or warm water as required, and the distances between the knots are subsequently measured again. The changes in length may then be reported as:

$$\text{Shrinkage (\%)} = \frac{\text{Initial length} - \text{final length}}{\text{Initial length}} \times 100$$

or:

$$\text{Length change to wetting (\%)} = \frac{\text{Final length} - \text{initial length}}{\text{Initial length}} \times 100.$$

In this latter case, shrinkage is reported as a negative quantity and elongation is reported as a positive quantity.[49]

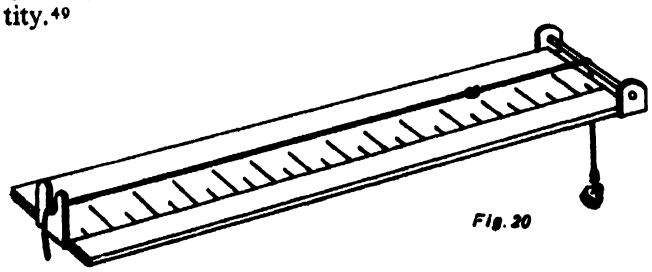


Fig. 20

Proposal (c): [50] Tests in cold water. A distance of 1,000 mm is marked on the test specimen under standard pre-tension and the specimen is tied outside the marks to form a loop. The specimen is immersed in water at room temperature for 12 hours or until it has become thoroughly soaked, and then it is dried. The new length is then measured in mm, as above, and the shrinkage is calculated by the first formula in Proposal (b) above.

Tests in boiling water: A test specimen more than 1 m long is folded in half and the two free ends are secured together. A standard, pre-tensioning load is applied to the loop and both sides of the loop are marked at a distance 50 cm from the fold. The test specimen is then boiled, unstressed for 30 min and is dried. The marked distance is measured again, as above, and the shrinkage is calculated as follows:

$$\text{Shrinkage (\%)} = \frac{500 - \text{final length (mm)}}{500} \times 100.$$

At least five tests should be carried out for each average.

(9) Thermal reaction

The actual properties of netting materials, particularly those made of man-made fibres, can be different from the measured properties at temperatures which differ from the specified standard temperature at which the properties were originally measured. This is true both for the higher temperatures experienced in the tropical fishing industry and for the lower temperatures experienced in the winter fisheries of most countries in the temperate and arctic climates. In particular, changes can be expected in strength, extensibility, and stiffness. Special equipment, required for measuring physical properties of netting materials at extreme temperatures, has not yet been developed by fishery researchers. To determine whether or not netting materials can withstand temperatures required for preserving or dyeing, boiling tests are usually carried out, particularly to establish resulting changes in length. Such tests demonstrate that the materials can be affected by temperature. The methods developed by the textile industry for measuring resistance to cold and heat should be remembered.[51]

(10) Weather resistance

Some properties of netting twines, especially strength, are adversely affected by light, particularly by ultraviolet radiation. Usually, light damage is studied by exposing the unprotected samples to natural sunlight in the open air. Since light is not the only factor in such exposures, the tests are often described as being for weather resistance or atmospheric resistance. In this test, quite a number of other factors affect the material:[52]

Primary exposure factors:
- chemicals in the air—oxygen, carbonic acid, water (steam, fog, dew, rain, snow, ice)
- temperature
- air movements (wind)
- solar radiation.

Secondary exposure factors:
- dust
- shifting sand
- micro-organisms and insects.

[48] van Wijngaarden, J. K.: Methods of testing net cord and nets, especially those made of synthetic material. Rayon Revue, 11, pp. 146-160, 1957.

[49] Carrothers, P. J. G.: The physical properties of netting and twine suitable for use in commercial fishing gear. Modern Fishing Gear of the World, pp. 69-74, 1959.

[50] Japan Chemical Fibres Association: The manufacture and testing of synthetic yarns and fibres used in Japanese fishing gear. Modern Fishing Gear of the World, pp. 62-68, 1959.

[51] E.g., Sommer, N. and Winkler, F.: Prüfung der Textilien. In: Handbuch der Werkstoffprüfung V, 1312-1335, 1960.

[52] Hofmeier, H.: Klimaprüfung zur Ermittlung der Gebrauchseigenschaften von Kunststoffen und anderen Werkstoffen. Kunststoffe 41, pp. 179-180, 1951.

In every case, changes in strength or abrasion resistance or fading of dyed materials have to be measured. When different materials are being compared, it should be recognised that light rays do not penetrate deeply so that materials of different diameter are differently affected.

For determining the effect of the sun's rays and weather in the open air, the samples are stretched in a frame (Fig. 22). These frames are set in an unshaded place (e.g., on a roof) free from dust and smoke if possible. They are faced in a southerly direction and are secured so they are not damaged by wind. The frames are built of wooden laths, 3 cm wide by 2 cm thick, and are varnished for protection against the weather. The size of the frame is governed by the size and number of the samples. Where strength is used as the measure of weather damage, a test length of 200 mm is required (see Section 1) so that the frame should be 30 cm wide. Several frames may be exposed together.

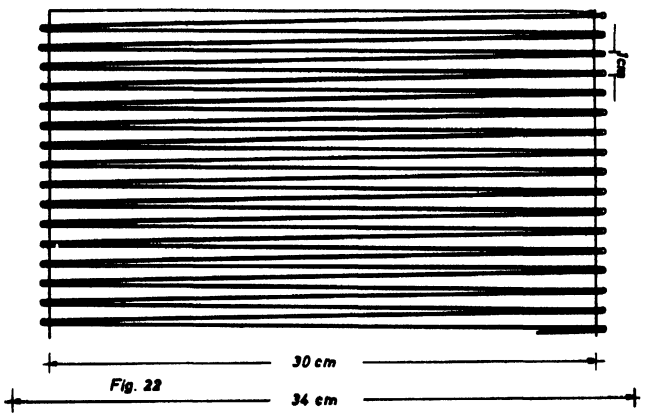


Fig. 22

The materials are suspended, without tension if possible, on aluminium nails or screws set 1 cm apart on the frame. The nails or screws on opposite sides of the frame are off-set $\frac{1}{2}$ cm so that the test material assumes a zig-zag shape (see Fig. 22).

Every two or three months test specimens are removed for measuring changes in strength or other properties. The measured result is referred to the total time of exposure or to the number of hours of sunlight measured during the exposure as reported by the local weather station.[53]

Resistance to sunlight: For determining the effect of sunlight completely exclusive of rain and dust, the materials may be exposed in a box covered with ultra-violet transparent glass. As for the weathering test, the box is set at an angle of 45° facing south, and the bottom of the box is ventilated to avoid overheating.[54]

The sample is wound around an opaque board, 30 cm wide, which is mounted in the box so that its upper face is 5 cm from the glass cover. The specimens on the shaded side of the board are used as controls for comparison with the specimens on the exposed side of the board. As mentioned above, the resulting change in properties is related to the number of hours of sunlight during exposure.

Resistance in weathering machines: It has also been proposed that accelerated tests be conducted with artificial radiation instead of with sunlight which requires a long exposure time. These weathering machines are constructed so that the samples may be exposed to artificial rain as well as to artificial sunlight, e.g., The American Weather-Ometer.[55]

(b) Chemical tests

(11) Resistance to preservatives, oils, etc.

Netting twines made of man-made fibres may be damaged by substances such as creosote oils and tannins which are used to preserve natural fibres as well as by fish slime and by other chemicals (e.g., light and heavy oils) used in the fishing industry which also damage natural fibres. Their effect, particularly on strength, should be studied.[56]

(c) Biological tests

Fishing gear made of natural or synthetic fibres can become damaged by various organisms both in storage and in use. However, storage tests which study damage in net warehouses will not be included here. Only those tests which assess damage to fishing gear by water-borne organisms will be discussed.

For netting materials made of plant fibres, cellulose-digesting microbes and fungi living in the water and in most storehouses are the major cause of rot. Similar damage by micro-organisms can also be experienced by fibres of animal origin.

Netting materials or natural and synthetic fibres can also be damaged by several higher-order organisms in the water. Here, our thoughts are restricted to those organisms which eat dead vegetable matter or gnaw at it for some other reason and, hence, which attack netting made of plant fibres, too. Those water animals which have become trapped in fishing gear and damage it in an effort to become free will not be considered. Among these could be members of all types of animals living in the water, including the fish themselves.

Finally, within the scope of biological tests is a study of that damage by communities of living animals or plants known as fouling, whereby the organisms move actively onto fishing gear which has been in the water for a while.[57]

[53] In connection with weathering tests, the amount of sunlight and precipitation and the relative humidity should be measured each day.

[54] Standard procedures specify that the ventilation be such that temperatures inside the box are no more than 2°C above the outside temperatures.

[55] Japan Chemical Fibres Association: The manufacture and testing of synthetic yarns and fibres used in Japanese fishing gear. Modern Fishing Gear of the World, pp. 62-68, 1959.

[56] See Chapter 16: Dyeability and treatability, and Chapter 17: Storability.

[57] Concerning organisms which are moved passively onto the nets, see Chapter 22: Pollution.

(12) Rotting resistance

If treated or untreated netting materials made of natural fibres are to be tested for rotting resistance, the conditions experienced by the fishing gear during fishing must be considered. Of great importance is the constant rinsing action by the water.[58] Tests, as conducted in textile research with pure cultures of certain micro-organisms such as fungi or with mixed cultures enriched to a greater or lesser degree with suitable micro-organisms as in the soil burial test,[59] can yield incorrect results with fishing gear materials, unless storability tests are being conducted (see Section 17), because there is no constant rinsing and consequent leaching of preservative agents.

The two tests described below refer, in the one case, to a field test in natural water and, in the other case, to a laboratory test. The objection[60] to the field tests in natural water is that non-biological factors such as currents, rinsing time, and mechanical effects can affect the result. The objection to laboratory tests, e.g., in aquaria, is that the test vessel can become poisoned by preservative agents leached from the test specimens and that leaching is slower than in the field so that rotting may be lower in the experiment than during fishing. So far, these difficulties have not been overcome. Nevertheless, by either procedure, comparable results may be obtained.

Proposal (a): test under natural conditions.[61] For measuring the resistance to rot under natural field conditions, the specimens are exposed in a suitable location under the surface of the water. Damage by the micro-organisms is measured by testing the strength of the specimen both before and periodically during the exposure. The lower the rot resistance of the material, the quicker it will decrease in strength, and vice versa. However, the rate of strength decrease depends also on the rotting activity of the water. Therefore, this must be measured at the same time. Thus, the duration of the test is determined on the one hand by the rotting activity (exogene factor) of the water and on the other hand by the rotting resistance (endogene factor) of the netting material. The exposure should be continued, if possible, until the specimen has lost at least 50 per cent of its initial strength. The rotting activity which causes the netting material to lose 50 per cent of its initial strength is taken as the measure of rot resistance. A greater required rotting activity to cause this loss indicates greater rotting resistance of the material.

Thus, the test consists of two parts: first, the rotting activity of the place where the exposure is to be made is determined and, second, the strength loss experienced by the specimen is measured. The rot resistance of the specimen is computed from both these values.

If the rotting activity of several test places is known, comparative tests can be conducted in these different places even during different seasons. Thus, the test results are independent of differences in exposure site and exposure time.

The monthly rotting activity of a new exposure site may be measured as follows:

Special cotton test twine of metric No. 50/15 (20 tex × 5 × 3)[62] is suspended in the water at the site in question on the first day of the month. Prior to exposure, the twine is first extracted by boiling in distilled water and its initial strength in the wet condition is measured; then pieces of it, each 30 cm long, are tied together by means of a rot-resistant material into four bundles of 10 pieces of twine each. After the first, second, and third week and on the last day of the month, one of the bundles of test twine is removed and its loss in strength is determined. The per cent loss in strength after one month is the rotting activity of that site during that month. For the above procedure, the loss in strength should not exceed 70 to 80 per cent of the initial strength.

In areas where rotting activity is high, a loss in strength equal to 70 to 80 per cent of the initial strength may be reached before the end of the month, even before the end of the first week. In this case, it is not possible to determine the monthly rotting activity by the above procedure.

The procedure must be modified so that the exposed specimens are replaced by new ones after they have lost $\frac{3}{4}$ of their initial strength. The time at which this loss occurs may be found easily by testing exposed specimens for strength loss every week as described above. For sites which have been used experimentally for several years, the time required for the strength loss to equal $\frac{3}{4}$ of the initial strength during any particular month is already known approximately. In such cases, the specimens may be replaced every week or 10 days as indicated. The per cent strength losses of all successive specimens, replaced one or more times during the month, are added together.[63] The total result is the rotting activity of that site during the month in question. Similar determination of the monthly rotting activity of a given site, by exposing the untreated specimens until they have lost only

[58] For netting materials made of synthetic fibres, which as a rule are not destroyed by cellulose- or protein-digesting micro-organisms, the methods described here may be used to measure their resistance to damage by the water or other agents in it.

[59] See proposal DIN 53933 and ASTM Designation D684-54.

[60] Zaucha, J.: Evaluation of rot-retarding net preservatives. Modern Fishing Gear of the World, pp. 128-132, 1959.

[61] v. Brandt, A.: Arbeitsmethoden der Netzforschung, Stuttgart, pp. 64-83, 1947, and Method of testing resistance of net materials to micro-organisms. Modern Fishing Gear of the World, pp. 133-136, 1959. This method is based on the so-called "physical-activity-determination" by Meseck (1929).

[62] In tropical areas, where the rotting activity is higher, heavier twines such as metric No. 20/45 (50 tex × 15 × 3) have been used.

[63] The rate of strength loss with time is not constant, being much slower at the beginning of the microbiological destruction than at the end. For this reason, strength losses greater than 70 to 80 per cent of the initial strength are not included in rotting activity estimates. Even so, some error cannot be avoided, but the simple summation of per cent strength losses can still be useful.

50 per cent of their initial strength, has already been described elsewhere.[64] Because the moment of the desired standard strength loss does not always fall at the end of the month, or because the exposure is not always started at the beginning of the month, daily values for per cent strength loss may be calculated as the basis for estimating the rotting activity which affects a specimen for periods less than a month.

In only very few cases are untreated netting materials tested for rotting resistance. Usually the materials have been treated with a preservative.

For measuring the efficiency of a preservative in reducing rot, cotton twines, e.g., metric No. 50/15 (20 tex × 5 × 3), or materials made of other fibres subject to rot, are treated according to directions for the preservative. For comparing different preservatives with one another, the same size twine should be used throughout.

The twine is cut into 60 cm lengths, the ends are knotted to conserve twist, and the specimens are treated. Then they are tested for increase in weight, content of certain active preservative agents, changes in flexural stiffness (Section 3), changes in length (Section 8), changes in strength (Section 1), etc. The pieces of treated netting material are folded in two and tied into bundles 30 cm long. Care must be taken that the material used for tying the bundles does not affect nor is affected by the treated test specimens, and that it does not rot itself. Otherwise, the bundles will become loosened before the end of the test period.

In test places where the current is strong, e.g., offshore or in rivers, etc., the specimens may have to be tied together at their lower ends as well as at their upper ends to prevent mutual damage or entangling. It must be noted that the specimens are rinsed more in sites having strong currents than in still locations. This stronger rinsing can decrease the resistance to rot. Results from places which differ widely in these non-biological factors should not be used for comparative tests.[65]

Each bundle of treated netting twine should consist of 60 test pieces (30 double twines). This number is sufficient for six tests of 10 twines each or 12 tests of five twines each. Larger bundles than this are not satisfactory because the outer twines protect the inner ones from the rinsing action of the water, particularly if the bundles are tied at both ends.

It is not necessary to rinse the bundles of treated twine before the test because, as with fishing nets, rinsing occurs automatically during the first few days of exposure. Specimens which have been treated with different preservatives should not be exposed close together, otherwise they may affect one another.

The specimens are exposed in such a way that they do not touch the bottom, or piles, or any other object. In offshore regions in the presence of tide, the specimens should be mounted deep enough so that they do not become exposed to the air at any time.

For assessing a new preservative, twines treated with it are exposed together with twines treated with a known standard preservative for comparison. All samples are exposed in the water at the same time. Under European conditions, the first test for strength loss is applied to the required number of specimens, e.g., 10, each 30 cm long, removed from the bundle after two or even three months of exposure.[66] As a rule, tests are repeated every two months in summer and every three months in winter unless an abnormal strength loss requires more frequent examination. The rotting activity is measured at the same time by the procedure described above.

The specimens taken from the exposed bundle are rinsed, any fouling, etc., is removed, and the breaking strength is determined immediately. If it is not possible to conduct the strength test immediately, the specimens are dried quickly and thoroughly and are stored under suitable conditions for later test for wet strength.[67]

The loss in strength of the treated specimens is compared with the rotting activity of the water, measured at the same time (see above). As already described, the rotting resistance of the treated specimens is reported as that rotting activity of the water which causes the treated specimens to lose 50 per cent of their initial strength. Usually, the exact rotting activity for this 50 per cent strength loss cannot be determined directly by experiment but must be computed by linear interpolation from the test strengths and rotting activities before and after the 50 per cent strength loss as follows:

$$\text{Rotting resistance} = \frac{(t_2 - t_1) \times (R_1 - R_{50})}{R_1 - R_2} + t_1$$

where:

t_1 = rotting activity which causes less than 50% strength loss

t_2 = rotting activity which causes more than 50% strength loss

R_1 = breaking load after exposure to rotting activity t_1

R^2 = breaking load after exposure to rotting activity t_2

R_{50} = 50% of initial breaking load

[64] Zaucha, J., Evaluation of rot-retarding net preservatives, Modern Fishing Gear of the World, pp. 128-152, 1959, has proposed to use the 50 per cent strength loss rather than the 70 to 80 per cent strength loss as the limiting value. In Proposal (b), the per cent loss in strength is not specified at all. Rather, the time for total rotting of the untreated twine is called a period, and the number of periods required for the treated twine to lose a specified per cent of its initial strength is used as the measure of rotting resistance.

[65] Results from test sites having low rotting activity will usually be lower than results from test sites having high rotting activity because rinsing in the former sites has greater effect through the longer test period.

[66] In tropical areas, specimens should be removed for test after two or three weeks, or, at most, one month.

[67] It has also been proposed to preserve specimens in formalin when they cannot be tested immediately. The German DIN 53932 (draft) has proposed 0·1 per cent 'Preventol CMK' for this purpose. This procedure should be satisfactory particularly for untreated twines which are being used to measure the rotting activity of the water.

the desired value for rotting activity is between t_1 and t_2.[68]

The results may be grouped as follows for classifying the efficiency of various preservatives:

rotting resistance up to 200 : no practical effect
200 to 500 : minor effect
500 to 1,000 : medium effect
1,000 to 2,000 : good effect
more than 2,000 : very good effect.

Proposal (b): tank test in laboratories.[69] The tank consists of a 12-litre bottle with a tightly fitting rubber stopper carrying a fermenting tube (Fig. 23). The tank is placed in a constant temperature water bath at 28°C (82°F). Ten litres of sewage sludge is collected in a bottle from the local sewage treatment plant as the source of supply for the rotting medium. This bottle of sludge is placed alongside the rotting tank in the water bath as soon as possible. Meanwhile, the following nutrient solution is prepared and placed in the rotting tank:

8 litres of tap water
10 g secondary potassium phosphate
10 g ammonium sulphate
0·1 g sodium chloride.

To this solution two litres of sludge from the supply bottle and a few sheets of filter paper torn into small pieces and shaken in water are added.

The rotting tank is allowed to remain at 28°C until the bacteria have begun to multiply (usually between one and two days). Then the pH is measured with an electric pH meter and is corrected to 7·5 with potassium carbonate. The rotting tank is now ready for use.

Samples of cotton twine treated with the preservative being tested are placed in the rotting tank along with samples of untreated twine as a control. The tensile strength of the untreated sample is checked daily. The pH is measured and adjusted every three days. When the bacterial growth ceases to cause a surface scum, more filter paper is added. The tank is stirred daily.

As soon as the tensile strength of the untreated twine has dropped to 0, all the samples are removed from the tank and are rinsed. This concludes the first exposure period. Thus, in this procedure, one period is defined as the time required for the complete deterioration of a sample of untreated twine of the same metric number as the treated samples.

Before a new exposure period is started, the samples of twine are rinsed in running water for three days. Meanwhile half the contents of the rotting tank are removed, one litre of sewage sludge is added from the supply bottle, the rotting tank is topped up with nutrient solution at 28°C, and the pH is adjusted to 7·5. Then the test samples are returned to the rotting tank along with a fresh sample of untreated twine as a control.

After each exposure period the tensile strength of the wet test samples is measured by performing five test breaks on the strength-testing machine using a 10 cm test length. The results of these tests are tabulated, reporting first the tensile strength after treatment with the preservative, then the percentages of this strength which remain after the first, second, third, etc., exposure periods.

Experimental procedure: Cotton twine, Nm 20/6 (50 tex × 2 × 3) (tensile stength = 6·0 to 6·5 kg), is used for this experiment. For each test, a total of about 40 pieces of cotton twine, each about 50 cm long, are cut. These pieces are folded in half, gathered into small skeins about 25 cm long, and treated with the preservative as desired.

Nylon lines, 30 cm long, are fastened between two circular plates made of a dense material. The test skeins of twine are fastened to these lines, and are identified by numbers marked on the circular plates.

In addition to the hole drilled for the fermenting tube, another hole is drilled in the centre of the large rubber stopper used to seal the rotting tank, and a glass tube 20 mm in diameter is inserted. This glass tube can be sealed with a smaller rubber stopper.

When the two circular plates with the sample skeins attached are lowered into the rotting tank, the lower plate settles to the bottom of the tank while the upper plate is suspended just below the surface of the fluid by a nylon line which is secured between the central glass tube and its smaller rubber stopper. Thus, the sample skeins are held in a vertical position in the rotting tank without touching each other. The contents of the tank are stirred daily by vertically moving the nylon line from which the upper circular plate is suspended.

The upper end of the sample of untreated cotton twine is similarly led through the central hole in the large rubber stopper, while a 250-g weight (less than five per cent of its initial tensile strength), tied to the bottom end of the sample, rests on the bottom of the rotting tank. After this, the tensile strength of the control twine is checked daily simply by lifting it by hand. When the untreated twine breaks, its strength must be between 0 and 5 per cent of its initial tensile strength (see Fig. 23)

This procedure gives results which agree quite well with those from field experiments, although there are certain exceptions.

1. When the preservative treatment gives the netting twine a coating of tar, plastic, etc., the results in the rotting tank are often better than in practice because the coating frequently forms an effective physical barrier against the bacteria in the tank whereas in practical use flexing and natural rinsing cause local breaks in the coating, thereby laying the twine open to bacterial attack at these places.
2. Certain preservatives are simply deposited on the twine. Since these agents may be washed very slowly from the twine, it is possible that the three-day rinse is insufficient and that the loading of preservative on the twine does not reach equilibrium until after the sample has been placed in the rotting tank. In this case, the preservative agent will migrate from this test sample into the water and

[68] For an example of this method see: v. Brandt, A.: Method of testing resistance of net materials to micro-organisms. Modern Fishing Gear of the World, pp. 133-136, 1959.
[69] Teknologisk Institut, Copenhagen.

onto the other test samples, thus causing erroneous results.

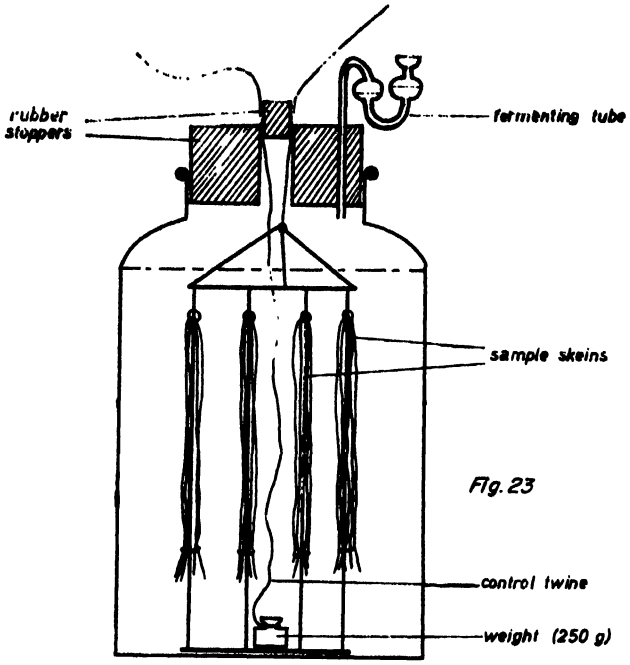


Fig. 23

(13) Resistance to macro-organisms

Because damage by other water-borne organisms (some insect larvae particularly of caddis and various sand-hoppers which gnaw the material, or wood borers such as ship-worms and gribbles which also attack cordage) cannot be tested during practical use, this must be done in laboratory aquaria[70] or in lath boxes which are immersed in natural waters.[71] The boxes are constructed in such a way that the organisms approach the test material, which is stretched and fastened in the boxes, from the side. The bottoms of the boxes are solid so that organisms which fall off the test material during exposure are not lost.

In laboratory aquaria the test may be conducted in such a way that the organisms are offered their ordinary food as well as the specimen of netting material. Otherwise, according to procedures developed for wood and textile vermin,[72] only the specimens of netting material are offered, nothing else. In the first circumstance the animals can select their food, whereas in the second circumstance they are forced to eat the netting material or die. The latter arrangement is the more severe test, and it will indicate whether or not the netting material will be taken as food in an emergency. Caddis use netting materials particularly to build their tubes.

(14) Fouling resistance

If netting materials and cordage are allowed to stand in water for a long time, plant and animal organisms can actively settle on them. The settling of these communities of living organisms on dead objects is known as fouling. Special test procedures have been developed for studying fouling on ships.[73] Such a test will be successful only if it is carried out in the field under natural conditions. The fouling conditions at the test site must be known. In this matter, the following has to be reported:

(a) The general development of the fouling, its composition and intensity during the course of one year
(b) Whether there is only one or several periods of fouling
(c) When the fouling periods begin and end
(d) The seasonal appearance of the different types of organism, singly or in groups, and the order of their arrival
(e) All organisms which settle first prerequisite to subsequent organisms.

As fouling can consist of many species of different animal and plant organisms,[74] it must be realised that treatments which can prevent fouling of netting material in one place can be useless in another where there are completely different organisms.

It is possible to assess the fouling activity either by the density or by the weight of the fouling organisms. The test may be conducted with gear used for fishing or with netting twines or cordage exposed specially for this purpose. The procedure for the test depends on the type of fouling.

Proposal (a):[75] Netting materials, netting, or cordage is exposed under water in a suitable place, if possible before the beginning of the fouling period. Fouling is observed continuously, particularly more frequently during the initial period of immersion.

For measuring fouling, the test sample is removed from the water for a short time and the fouling intensity is recorded photographically. For comparative values, the fouling density is reported as the per cent of the surface area which has become covered during the exposure period. Fouling density should be reported more precisely when it is light than when it is heavy. For example, the following classes of fouling intensity are proposed:

free of fouling = 0%
partial fouling = 1, 3, 5, 10, (15), 20, 30, 50, 60, 80, 90%
maximum fouling = 100%.

Finally, the fouling is removed at the conclusion of the exposure to determine to what extent the surface fibres of the netting materials have been affected by the fouling.

Proposal (b):[76] The specimens of netting material are immersed in water for a sufficiently long time to become

[70] v. Brandt, A.: Arbeitsmethoden der Netzforschung, Stuttgart, pp. 83-85, 1947.
[71] Meseck, G.: Untersuchungen über den Netzfrass niederer Wassertiere, etc., Zeitschrift für Fischerei XXVI, pp. 237-310, 1938.
[72] Becker, G.: Biologische Untersuchungen an Textilien. Handbuch der Werkstoffprüfung, 5: Prüfung der Textilien, pp. 971-1007, 1960.
[73] Kühl, H.: Arbeitsmethoden für Untersuchung von Bewuchsschutzmitteln. Veröffentlichungen des Instituts für Küsten-und Binnenfischerei, Nr. 16, 1957.
[74] Ray, D. L.: Marine boring and fouling organisms. Seattle, 1959.
[75] In accord with fouling tests for ships. Kühl, H.: see [73] above.
[76] Takayama, S. and Shimozaki, Y.: Development of fishing net and rope preservation in Japan. Modern Fishing Gear of the World, pp. 113-122, 1959.

thoroughly soaked, then they are weighed on a spring balance and exposed at the test site. Periodically, the specimens are removed from the water, allowed to drain, and weighed, complete with the organisms which have settled on them, on the spring balance. Results with variously treated materials are shown in Fig. 24.

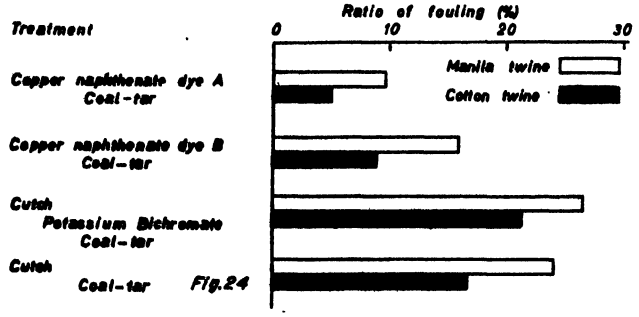


Fig. 24

(d) Tests for suitability

The way in which different netting materials are best used in fishing gear and the way in which they are best handled during fishing can be determined only during practical use. Usually the assessment will be a subjective one. Sometimes quite effective netting material is rejected by the fishermen because it has other disadvantages, e.g., if it is too hard or cuts the hands when handled. Only a few of these properties, which are important during practical fishing, can be measured in the laboratory.

Also in this category should be mentioned the ease with which the netting twine can be made into netting, its amenability to or need for dyeing or treating with a preservative or stiffening agent and its storability when not in use.

(15) Processability[77]

Netting materials, e.g., twines, can be manufactured into netting by manual, semi-mechanical, or mechanical means. This is usually accomplished by knotting the netting materials. Recently it has also become possible to manufacture netting mechanically without knots. Whether or not the netting material can be knitted easily by manual or mechanical means must be determined by practical tests. This processability depends upon strength, particularly knot strength (Section 1), elasticity (Section 2), flexibility (Section 3), and on surface roughness (Section 7). The last two properties also affect knot stability (Section 20) and mesh strength (Section 19).

Manufacturing time can be measured, for either manual or mechanical netmaking, to determine whether the processing speed for a material under test is greater or less than that for a known material of equal value.[78]

The major causes of delay during manufacture of netting are breakage of the netting material, excessive surface roughness, adhesion as a result of static electricity, and the formation of unwanted loops and kinks. For assessing netting materials in this way, certain types of fishing gear or pieces of netting are manufactured by experienced netmakers. Manufacturing time is measured and manufacturing difficulties are recorded as the basis for comparison between the new and conventional materials. This test procedure can be similarly applied to mechanical netting manufacture. Where the netting manufacture is fully mechanical, the average number of rows of knots per unit time and the amount of waste are measured. The average number of rows of knots tied per unit time will be decreased every time the machine is stopped because of difficulties. Also the amount of waste cut from the netting, expressed as per cent of the amount of good netting manufactured, will be increased by a greater difficulty in processing.

(16) Dyeability and treatability

Before new fibres can be used for practical fishing, it should be determined whether or not they can be dyed or otherwise treated for stiffening, etc., without damage. Some synthetic materials are thermoplastic, and soften and shrink (see Sections 8 and 9) even at temperatures which are commonly used without damage for dyeing or treating netting materials made of natural fibres.

It is also possible that other chemicals, which are used for treating fishing gear or which are used for other purposes in the fishing industry and come in contact with the netting twines, can damage these netting materials (see Section 11, Resistance to preservatives, oils, etc.).

Often the textile industry offers dyes for man-made fibres which are too expensive for the fishing industry or which cannot be used by the fishing industry because they require special dyeing equipment. In such cases, other suitable processes must be sought.

In this matter, the fastness of the dyes, e.g., against exposure to light (Section 10), as well as dyeability must be considered. The fastness of dyes or of other treatments may be measured during the tests for weather resistance (Section 10), for rot resistance (Section 12) or by one of the following proposals.[79]

Proposal (a), salt-water test: Two samples of the netting material are placed in a solution containing three per cent sodium chloride (NaCl) and 0·5 per cent magnesium chloride ($MgCl_2$). After 24 hours immersion the samples are rinsed in fresh water and dried. The changes in colour and in stiffness (through loss of treating agent) are noted.

Proposal (b), agitating test: Samples of netting larger than 10 cm^2 are subjected to the action of a suitable agitator (washing machine) for 10 hours in water at 20 ±5°C. Then they are rinsed in fresh water and dried. The change in colour is noted and the loss of treating agent is measured by weighing.

[77] v. Brandt, A.: Arbeitsmethoden der Netzforschung, Stuttgart, pp. 54-63, 1947.

[78] Different netting twines are of equal value if they may be interchanged for practical fishing. Between twines made of different fibres, there are seldom two of identical count. Very often substitution is made on the basis of equal wet knot strength, but this cannot always be done, e.g., if one of the twines is so fine that it is difficult to handle.

[79] Japanese Industrial Standard (draft) J.I.S.L., 1958, Method 5-15.

(17) Storability

Untreated or treated netting materials can also suffer damage even by nothing more than protracted storage under normal climatic conditions. This can be observed particularly with treated materials which have not yet been used but which have experienced a loss in strength. It is possible, too, that netting materials stored under pressure can be damaged by spontaneous combustion, particularly if they are damp.[80]

For testing storability, netting materials should, as a rule, be held for a long time in a dry, shaded, and well ventilated place to simulate storage conditions. Strength of the netting material is measured periodically as described in Section 1. Of course, the intervals of measuring have to be very long.

For testing spontaneous combustion, the netting materials are stored in large piles which may be moist. Thermometers may be inserted into the pile of netting, even by the fishing industry itself, to measure its temperature. Smaller netting samples, or even the agents which cause spontaneous combustion, may be tested by the Mackey test for which the procedure has not been standardised.[81]

The effect of warm and moist storage can be deduced from soil-burial tests. The test described above (Section 12) for rot resistance in water cannot be used for testing storability. Similarly, the soil-burial test cannot be used for testing rot resistance under fishing conditions.

Proposal (a), soil-burial test for assessing storability under damp conditions.[82] For this test, soil-burial boxes (e.g., $45 \times 30 \times 25$ cm), of an air-permeable material (e.g., wood or asbestos-cement, but not glass), are filled with soil to at least 150 mm deep. The soil should be a well-seasoned compost, and should have a moisture content of about 20-35 per cent, based on the dry weight. Soils which contain loam or clay are not suitable. The boxes are kept at 29 ± 1°C (84°F) in a room whose atmosphere is saturated with moisture (100% RH).

For determining soil activity six cotton test twines, of metric number 50/15 (20 tex × 5 × 3) and each 30 cm long, are buried vertically in the soil so that only a short part (ca 5 cm) is not covered, and the soil is pressed lightly toward the test twines. The samples should be at least 50 mm apart. The boxes are weighed at the beginning of the test and the weight is checked daily.

Water lost by evaporation is replaced by spraying warm (29°C = 84°F), chlorine-free water over the test soil. After four days in the soil the twine samples are removed and tested for strength. When the twine strength decreases by 50% ± 10 during the four-day burial period (80 ± 10% during a seven-day period), the mixture in the box is active enough for use.

Meanwhile, the samples which have already been treated with the preservative are rinsed in tap water for 24 hours at 20°C (68°F) a flow rate at such that the water is renewed five times per hour. They are then ready for testing.

If the boxes of soil are sufficiently active, up to 20 specimens of treated twine each 30 cm long are buried as described above along with six similar, untreated twines for control. The untreated control twines are replaced every four days. Five of the treated twines under study are removed every two weeks, rinsed, and tested for strength. The test is seldom continued for longer than eight weeks. Usually four weeks is sufficient.

By testing the untreated control twines it is possible to determine the rotting activity or the number of rotting periods affecting the treated samples during the test (see Section 12).

It must be pointed out that the results of soil-burial tests are inherently affected by experimental conditions, and since conditions of soil burial differ somewhat from conditions in damp storage, the results from the soil-burial test should be interpreted cautiously.

A better test for storability may be to inoculate samples of the netting material with a standard culture of fungi, to incubate the infected sample in a warm, moist atmosphere, and to check the strength samples at regular time intervals. Such tests require special bacteriological laboratories which are usually not associated with fishery research institutes.

B. Testing of netting

The term "netting" refers to textiles which consist of one yarn or one or more systems of yarns which are crossed or joined so as to form meshes in the final product, or to meshed structures which are formed by other means such as by stamping or cutting sheet materials or by extrusion.[83] Usually the mesh assumes a diamond shape, seldom square. In knotless netting the meshes are sometimes more or less honeycomb shaped (hexagonal).

Netting may be classified as follows, according to the structure of the fabric,[84] see Fig. 25:

1. Knotted netting—usually made with the weaver's knot or reef knot or double-knot modifications of both types.
2. Knotless netting—either by the twisting technique or by the Raschel procedure.
3. Marquisette—leno or mock leno weave (cf. gauze).
4. Woven netting—open plain weave (cf. cheese cloth).

The chemical, biological and suitability tests described above for netting twines may be similarly used for testing netting. However, it is usually more convenient to apply such tests to netting twines than to netting.

There are, however, quite a few physical tests which refer particularly to the mesh or to the knot. These can be of great importance in the evaluation of netting fabrics and, hence, also of netting twine.

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[80] v. Brandt, A.: Arbeitsmethoden der Netzforschung, Stuttgart, pp. 87-91, 1947.

[81] Schniffner, R.: Untersuchungen von textilien Hilfsstoffen. Handbuch der Werkstoffprüfung Vol. 5: Prüfung der Textilien, pp. 858-912, 1960.

[82] In accordance with DIN 53933. See also ASTM Designation D684-54, ASA L 14.55-1960, Norme Française NF X 41-503-1955. Indian Standard 1623 and 1633, 1960.

[83] According to draft proposal by ISO/TC38/SC9.

[84] According to Japanese Industrial Standard (draft) J.I.S.L. 1948: Testing methods for synthetic fishing nets, Sections 2-8.

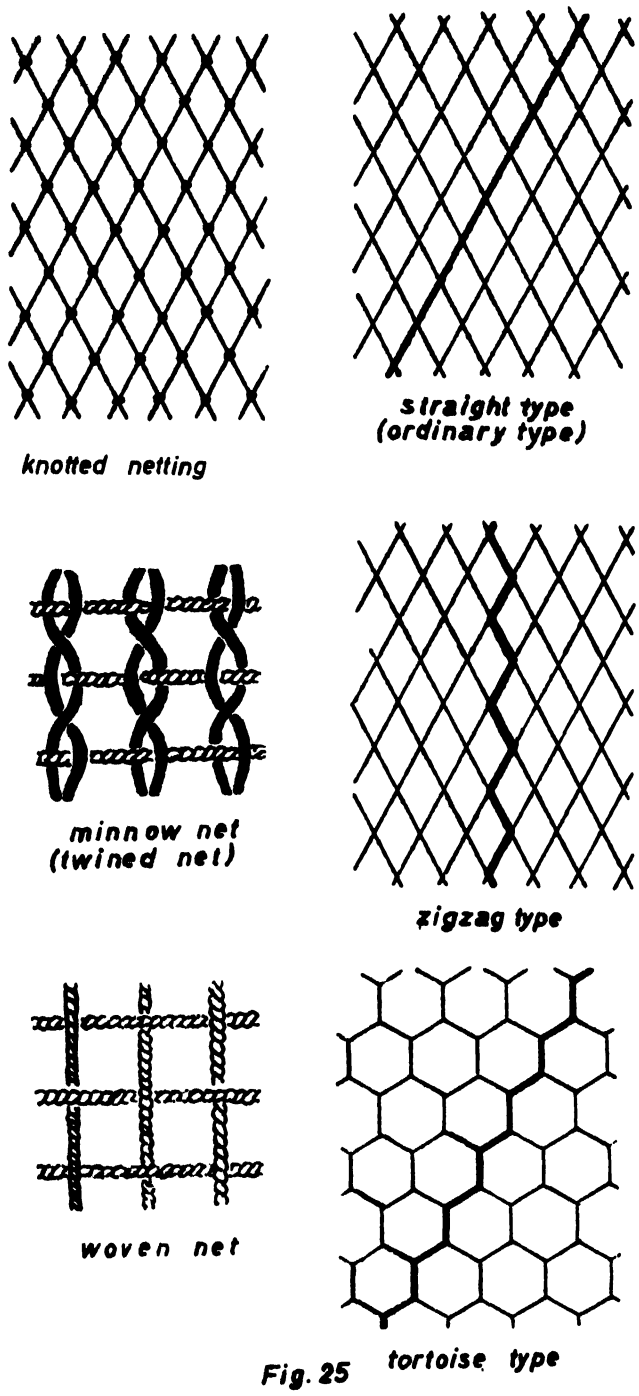


Fig. 25

indicated by the number of meshes which lie in one row oriented in the direction at right angles to the direction of the length indication.[85]

Mesh size: The size of the mesh may be indicated as the length or as the opening of the mesh. The mesh length in knotted (or knotless) netting is the distance between the centres of two opposite knots (or opposite joints) in the same mesh when the mesh is fully extended at right angles to (or parallel to) the continuing direction of the twines (Fig. 26, (a)—(b)), whereas the opening of the mesh in knotted (or knotless) netting is the inside distance between two opposite knots (or opposite joints) in the same mesh when the mesh is fully extended at right angles to (or parallel to) the continuing direction of the twines (Fig. 26, (c)—(d)).[86]

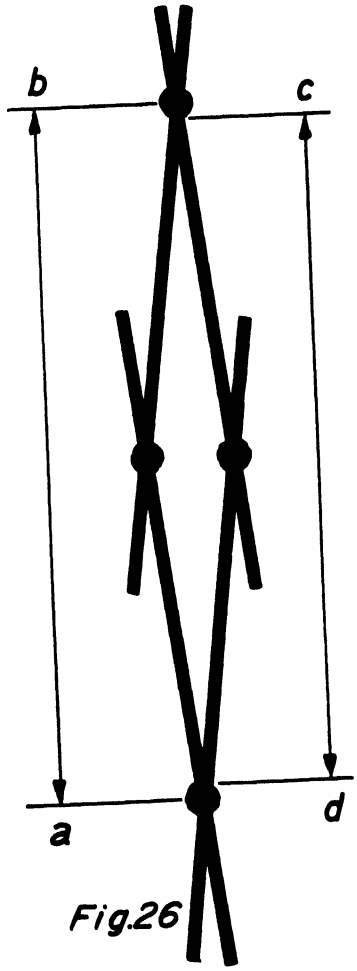


Fig.26

(18) Netting Dimensions

Two types of dimension pertinent to netting have to be considered: the overall proportions of the netting fabric and the size of the meshes. Particularly for measurement of mesh size, quite a variety of instructions have been issued, because most regulations for the protection of fish populations are based on the specification of mesh size.

Length and breadth: The length of a piece of netting may be indicated either by the number of meshes or by the number of meters. The breadth (depth) is always

The mesh size may be measured in many different ways. In addition to the fact that with hand-made netting the circumference of the spool is taken as a measure of mesh size, there are three basic principles underlying all these different ways for measuring mesh length. These are:[87]

[85] According to DIN 61250 (draft).
[86] ISO/TC38/SC9: Basic terms and definitions for textile products for fishing nets. Draft, May 1962.
[87] v. Brandt, A.: Zur Technik der Bestimmung der Maschengrösse. Archiv für Fischereiwissenschaft 6, pp. 54-64, 1956.

(a) By direct measurement of knot spacing. The distance between knots on opposite sides of the same mesh or beside one another in the same mesh is measured with a graduated rule. The place on the mesh where the rule is read depends on whether the mesh length or the mesh opening is being measured. It makes a difference whether or not the knot is included.

(b) By inserting a mesh gauge into the mesh to measure the space surrounded by the mesh. Recently, the type of mesh gauge and the required force have been standardised.[88]

(c) By counting the number of knots per unit length. In this procedure, the netting is fully extended and the number of knots within a known length are counted.

Since the recommendations for mesh size are designed to allow smaller fish to escape, only the mesh opening is significant. Therefore, only those procedures which have been developed for measuring mesh openings will be treated here. Knot size and twine diameter of the netting material are not considered. Particularly in heavy netting it makes a difference to the result whether or not they are included in the measurement. In finer (ratio of twine diameter to mesh length is small) netting it makes little difference whether or not the knot is included.

In the netting trade it is customary to measure the mesh size by gathering the netting lengthwise and by measuring the distance between opposite or successive knots, including one knot.

In the following proposals for mesh-length measurement, only wet netting will be considered because gear selectivity is determined by the size of the wet meshes.[89] For the netting manufacturer it is important to know the relationship between the sizes of wet and dry meshes. Thus, the length of dry meshes may also be measured by the following procedures to determine changes in mesh size (shrinking or lengthening):

As indicated above, a mesh gauge is inserted into the mesh to measure its opening. For this, there must be a certain force to straighten the mesh. There is no general agreement as to how great this force should be for different materials. As discussed above for unknotted netting materials, any standard should relate the magnitude of the straightening force to the weight of the material, e.g., equal to the weight of a certain length of the material, preferably the 250 m weight. (See proposal (d) in this Section). Because it is difficult to measure the weight per unit length of knotted netting materials which have already been used, it becomes necessary simply to specify a certain force during measurement of mesh size and to relate the measurements with different materials to the fishing selectivity of those materials. So far, no method has been developed for measuring mesh size whereby the relation between the measured mesh size and the selectivity of the fishing gear is the same for all types of material.

Proposal (a): mesh measurement in trawls for the marine fishery.[90] The mesh is measured by the so-called "ICES Mesh Gauge" with locking device,[91] which acts longitudinally to exert a standard force on the mesh. (Fig. 27) This gauge yields more consistent results with

[88] Prospectus of the ICES Mesh Gauge. Le Bureau du Conseil Permanent International pour l'Exploration de la Mer, Charlottenlund, Denmark, 1962.

[89] However, gear selectivity depends not only on mesh size but also on the shape of the meshes and on other internal and external factors.

[90] According to a proposal of ICES, Report of the Mesh Selection Working Groups Meeting in Copenhagen, December 1959 and 1960, Part IV, General Considerations on Trawl and Seine Mesh Selection and its Measurement.

[91] Fig. 27 shows different types of gauges which exert a force on the mesh. (1) ICNAF type, (2) Scotch longitudinal-force mesh gauge on which the ICE Smesh gauge was based, (3) Polish longitudinal-force mesh gauge, (4) Lowestoft "scissors" gauge.

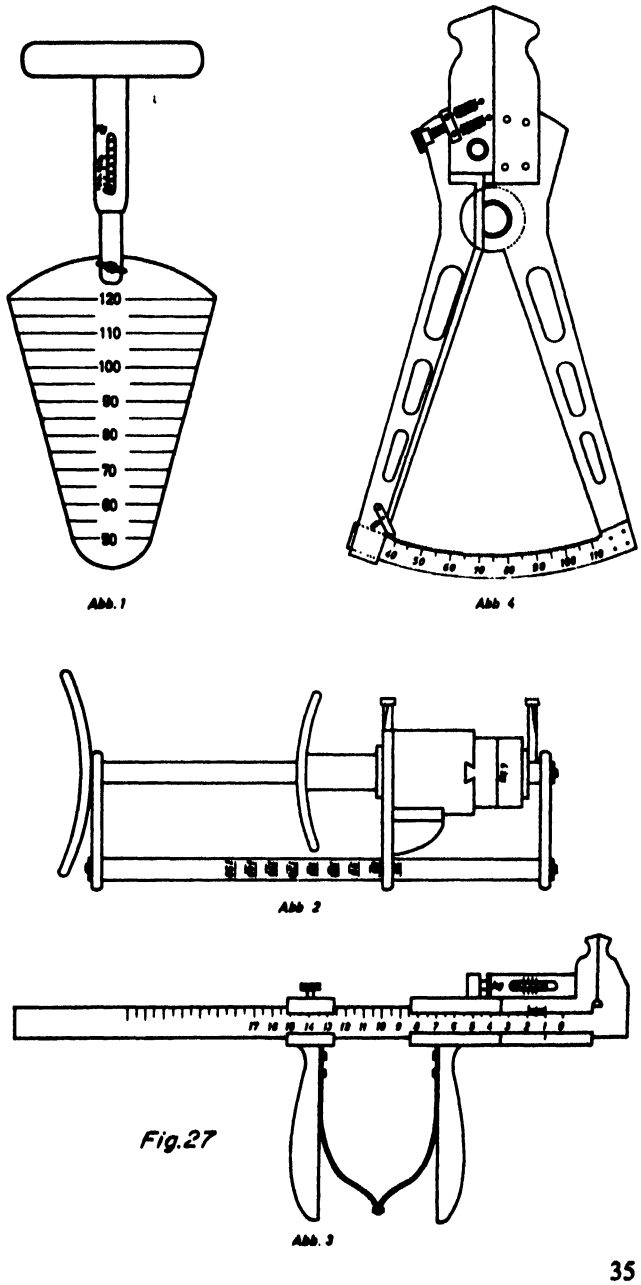


Fig. 27

different people[92] than does any other gauge by virtue of its design and construction. Because measurements of mesh size must be exactly c nparable for mesh selectivity studies, it is recommended that all other gauges used for such work be calibrated against this type of gauge as standard.

In particular, a force of 4 kg is exerted on the mesh when measuring mesh size in codends of trawls and seine nets. It is recommended that the gauge be recalibrated regularly. The codend must be completely wet. It is recommended that the meshes chosen for measuring should be in straight lines running fore and aft along the top side (not near the selvedges) of the after half of the codend, starting from the third row behind the codline. Meshes adjacent to strengthening ropes, meshes with a join in any bar, and meshes in any repaired part of the codend should not be measured. The measurements should be made immediately after every haul so that any change in average mesh size with time can be detected and reported.

The number of meshes to be measured should not be fixed arbitrarily because the minimum number of measurements is governed by the desired accuracy of the average and on the standard deviation of the mesh size which, in turn, varies with the original construction and use history of the codend. Usually, the average mesh size must be determined with an error less than two per cent. For this, it will usually be sufficient to measure 25 meshes if the observed 95 per cent range of mesh sizes is 20 mm and the average of measurements must be within 2 mm of the actual mesh size. In scientific reports, the number of measurements and the standard error of the average mesh size should be reported along with the average mesh size and range of mesh sizes.

The mesh size is reported in mm and the average is reported as the mesh size for that codend.

Proposal (b): mesh measurement in gillnets made of fine material.[93] This measurement is made on a special gauge as represented in Fig. 28. A panel of the netting, five meshes long by five meshes broad (deep) is cut from the gillnet. The rows of meshes along the upper and lower edges of the panel are respectively attached to hooks A and B and the gauge is suspended vertically from point C as shown in Fig. 28. The load D (1 kg) applies a tension to all five rows of meshes and the total length of five meshes is read at point F on scale E. This length divided by 10 gives the average length in mm of each mesh bar[94] taken from one knot to the next, including one knot.

Proposal (c):[95] The average measurements of 12 individual meshes in gillnets is taken as mesh size for the net. Three of these meshes are selected from each lengthwise quarter of the net, one randomly from the top third of the net (i.e. from the third nearest to but not including the corkline selvedge), one from the middle third, and one from the bottom third exclusive of the leadline selvedge.

The following measuring devices are recognised for measuring the mesh size (Fig. 29): the Allen net rule, the Hovey gauge, the Selkirk gauge, the flexible rule, and the straight rule. These devices apply a tension between three ounces (85 g) and eight ounces (225 g) to the mesh at the time of measurement.

The Allen gauge consists of a threaded rod along which the internally threaded sleeve C (Fig. 29) can travel. The block D is moved along the rod by turning sleeve C to which it is attached, but the block itself is restrained from turning on the rod by flats which are milled on either side of the rod. The mesh to be measured is placed

[92] v. Brandt, A. and Bohl, H.: Maschenmessung mit Druckmessgeräten bei Schleppnetzen. Protokolle zür Fischereitechnik 5, pp. 277-295, 1959.

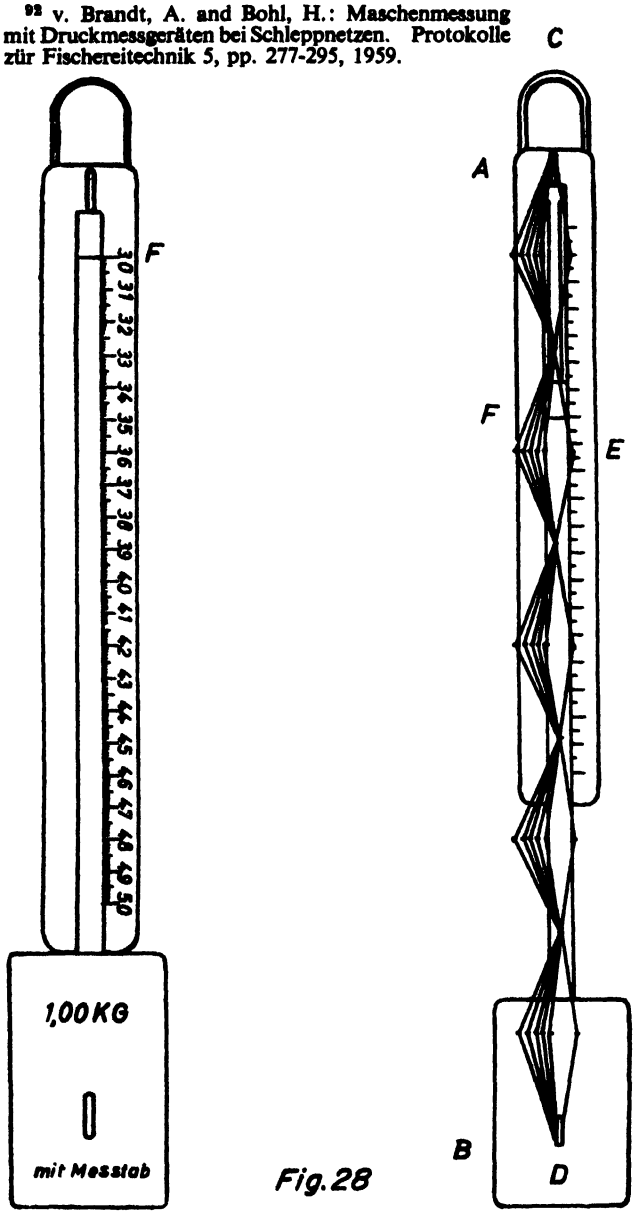


Fig. 28

[93] Florin, J.: Ein Messgerät zür einheitlichen Bestimmung der Netzmaschenweiten. Schweizerische Fischerei Zeitung 65, pp. 243-244, 1957.

[94] According to the ISO draft mentioned above, the term "bar" is defined as the distance between two sequential knots or joints, measured from centre to centre.

[95] According to Canadian Government Specification Board, Specification for Nets: Fishing, 25 April, 1958, and Fisheries Research Board of Canada, St. Andrews, N.B.

in the notches at A and B, and the sleeve C is turned by hand, moving the block D and the hook B away from hook A until the mesh becomes tight. The tension in the mesh pulls on the lever at B so that it pivots about point P and compresses the spring until the dog on the lever drops into one of the notches in sleeve C, stopping it from turning. The mesh opening is then read directly from the scale which is engraved on one of the flats on the rod. By proper selection of the spring, this gauge exerts a consistent tension of about five ounces (140 g) on the mesh at the time of measurement and gives more consistent results with different persons than do the other gauges.

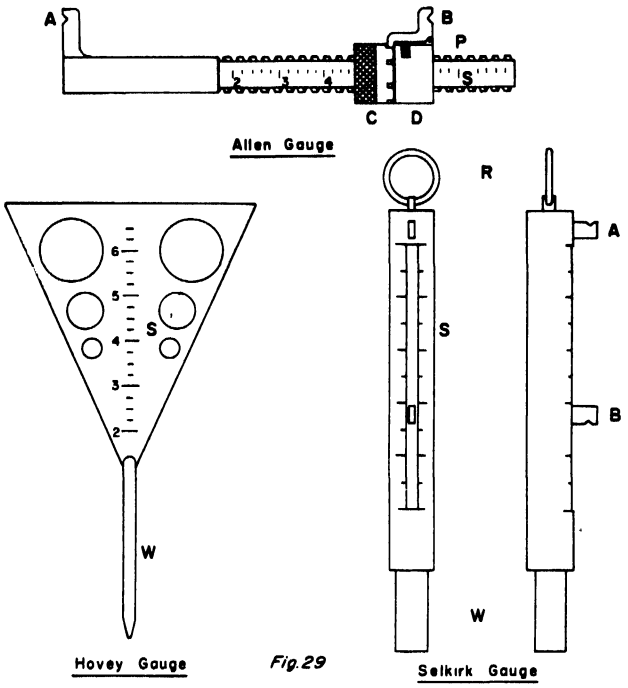


Fig. 29

The Hovey gauge (Fig. 29) operates on the same principle as the ICNAF gauge. The weight W is inserted into the mesh until the edges of the wedge rest against opposite knots in the mesh. The mesh is held horizontal so that the gauge hangs freely and the weight W (8 oz) exerts a standard force on the mesh. Care must be taken not to overstress the mesh while holding it. The mesh opening is then read directly from Scale S.

The Selkirk gauge (Fig. 29) consists of a cylindrical tube with a longitudinal slot cut in its wall, with a scale S engraved against the slot, and with a hook A fastened near its upper end. A rod W of standard (8 oz) weight is inserted into the lower end of the tube and the hook B is fastened near its upper end. The mesh to be measured is placed in the notches at A and B and the gauge is suspended from its ring R so that the weight W exerts the standard tension on the mesh. The mesh opening is then read directly from Scale S.

The flexible rule is a go-no-go gauge used for enforcing fishery regulations. It is a piece of flexible steel, $\frac{1}{2}$ in (1 cm) wide by 1/100 in ($\frac{1}{4}$ mm) thick and the same length as the minimum allowable mesh opening. The rule is flexed to a slight curvature and is inserted into the mesh so that each end rests against one of the diagonally opposite knots in that mesh. The rule is then released. If the rule straightens out, the mesh opening is satisfactory if the rule is held curved by the mesh, the mesh opening is too small.

The straight rule is a thin, graduated rule, usually made of steel. The index end of the rule is placed against one of the knots in the mesh to be measured and the opposite knot is pulled along the rule until the mesh is straight but not stretched. The mesh opening or the mesh length is then read directly from the scale on the rule.

The measurement is usually made by these gauges inside the mesh, i.e., between the knots (mesh opening), and with the mesh fully extended in the direction normal to the selvedge.[96] The result is reported in inches to three significant figures.

Proposal (d):[97] Although in this method, as in Proposal (b), the knot is included in the mesh size measurement, this is of little importance when the mesh opening in fine netting is being measured.

The mesh size is measured by a metric scale as the distance between the centres of opposite knots (mesh length) while the mesh is loaded by a pre-tension which causes no noticeable extension of the sample. For man-made fibres, this pre-tension in grams equals 1/30 of the total denier of the netting twine. Neglecting twist contraction, this is equivalent to the 300 m weight.

At least three measurements are made and the average is reported in cm to the first decimal place.

(19) Strength and extensibility

The term "strength of netting" is usually used to mean mesh strength, although, less frequently, it refers to the bursting strength of a piece of netting or to the tearing strength. If the usual strength-testing machines are used, the extension of the piece of netting or of the single mesh under load can be measured at the same time as the strength.

Mesh strength: To determine the strength of finer netting, the fisherman places two fingers in the mesh and tries to break it. He judges the mesh strength not only from the resistance to breaking but also from the sound of the break. The quantitative test is carried out in a similar way. The strength-testing machine is fitted with two pins which go into the mesh and pull it by an increasing force until it breaks.

Proposal (a):[98] The test for the strength of dry or wet netting is applied to single meshes. These test meshes are cut from the netting in such a way that the cut ends of twine are at least $\frac{1}{2}$ in (12 mm) long if the mesh is large enough, and, in any case, no closer to the test mesh than the mid-point of the cut bar.

[96] The selvedge is considered to run parallel to the general course of the twine through the netting.

[97] Japanese Industrial Standard (draft) J.I.S.L., 1958: Testing methods for synthetic fishing net (2-9).

[98] According to Canadian Government Specifications Board. Specification for "Nets: Fishing", 55-GP-1, 25 April, 1958.

The test is conducted on the usual strength-testing machines (see Section 1) on which the clamps have been replaced by pins which stand at right angles to the direction of pull. These should be sufficiently rigid that they do not bend noticeably when stressed by the test mesh. On the other hand, they should be fine enough that the mesh can be placed on them without any of the knots touching them, because, for the test, the mesh should be placed over the two pins in such a way that none of the four knots touches either of the two pins (Fig. 30). Thus, the test is conducted with the mesh stressed diagonally to the usual mesh shape.

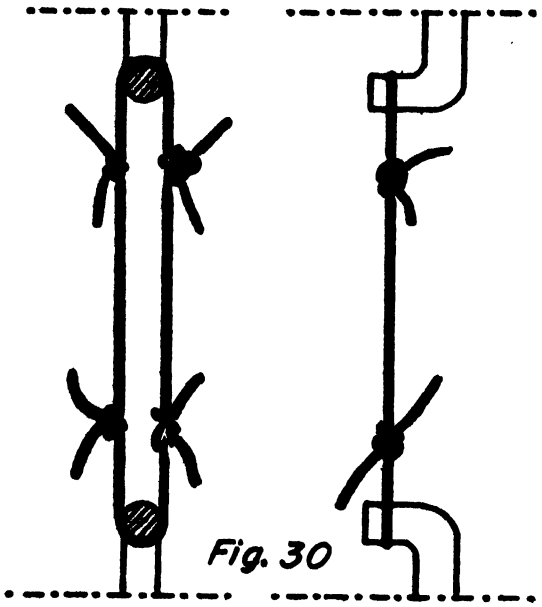
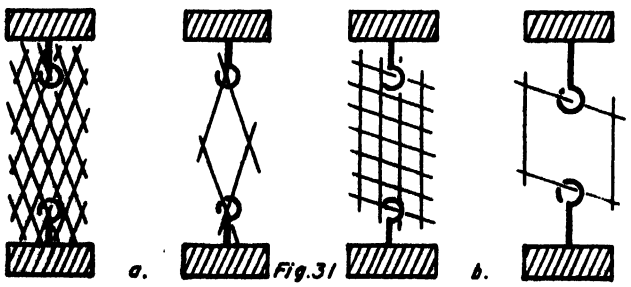


Fig. 30

The average of ten test breaks is reported as the mesh strength, and this may also be reported as a per cent of twice the strength of the netting twine to indicate mesh-strength efficiency.

Proposal (b):[99] For this test, too, the usual strength-testing machine on which the usual clamps have been replaced by hooks five to eight mm in diameter is used. Either a piece of netting or a single mesh may be tested (Fig. 31). The mesh is stretched over the hooks in its usual shape or at right angles to it, i.e., so that one of the knots touches each hook. Otherwise, the mesh may be stretched diagonally without any of the knots touching either of the hooks as described in Proposal (a), Fig. 30.

[99] Japanese Industrial Standard (draft) J.I.S.L., 1958 (5-10).



a. Fig. 31 b.

The initial distance between the two hooks is 10 cm and the rate of loading hook traverse is 15-30 cm/min. The mesh strength is taken as the average of 10 tests and is reported in kg to three decimal places.

Proposal (c):[100] Knotless netting is tested in the same way as described in Proposal (a), except that loops of twine of sufficient diameter and strength are used instead of the pins.

Sometimes a single mesh which has been cut from a piece of netting cannot be tested because of loosening and slipping in the junctions. In this case, instead of cutting off a single mesh, small pieces of netting are cut and the single mesh in the centre of each piece is tested according to Proposal (a).

In contrast to knotted netting, knotless netting which has been made by the Raschel process has noticeably a different strength when stressed in its usual shape (i.e., in the direction of the breadth or depth of the netting normal to the general course of the yarns) than when stressed at right angles to this (i.e., in the direction of the

[100] Institut für Netzforschung, Hamburg.

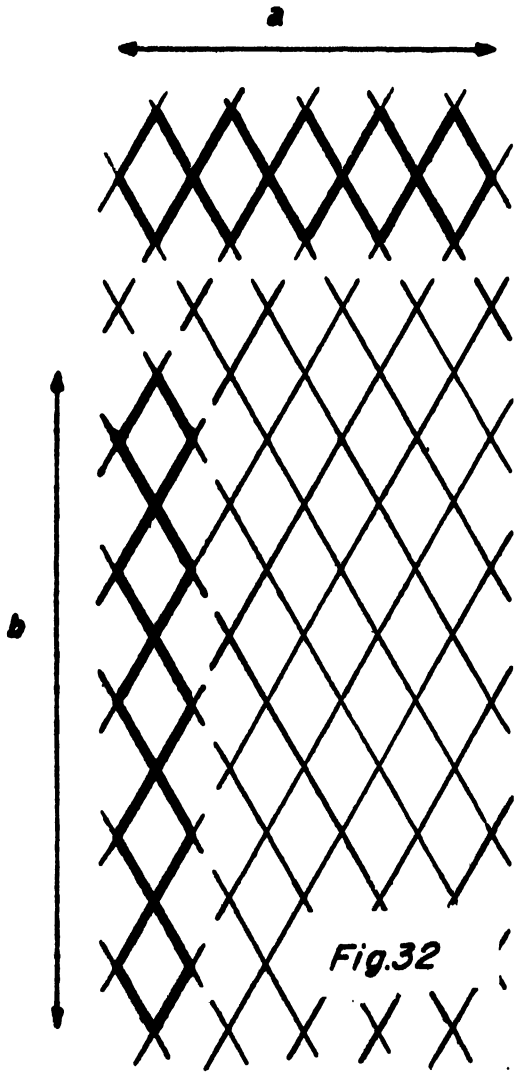


Fig. 32

length of the netting). The strength when stressed vertically (former case) is usually the lower one. For this test, rows of single meshes are cut from the netting both vertically and horizontally and each row is stressed in the usual fabric clamps on the strength-testing machine (Fig. 32). The initial distance between the clamps is 10 cm. Care must be taken that no knots or joints are caught between the faces of the clamps, otherwise the twine may become cut at that knot or joint before the mesh breaks.

The strength in both directions is measured and the difference is reported as a per cent of the higher value.

Netting strength: The term "netting strength" is used in more than one way. Sometimes it means the bursting strength of uniformly stressed netting and sometimes it means the diagonal tearing strength of pieces of netting such as those used for mesh-strength tests in Proposal (b).

The bursting-strength testers used in the textile industry cannot be used for measuring the bursting strength of netting under uniform load, particularly if the netting has large meshes. The knots are squeezed by the frame and the netting breaks there. [101] [102]

[101] Results of bursting-strength tests with fine (Nm = 70 and higher) netting on makeshift apparatus have been reported by v. Brandt, A.: Untersuchungen über die Maschengrösse. Protokolle zür Fischereitechnik, 5, 1951.

[102] For woven or other very small mesh netting the usual bursting-strength tester of the textile industry may be used. The average of the results of 10 tests is reported in kg/cm², Japanese Industrial Standard (draft) J.I.S.L., 1958 (5-13).

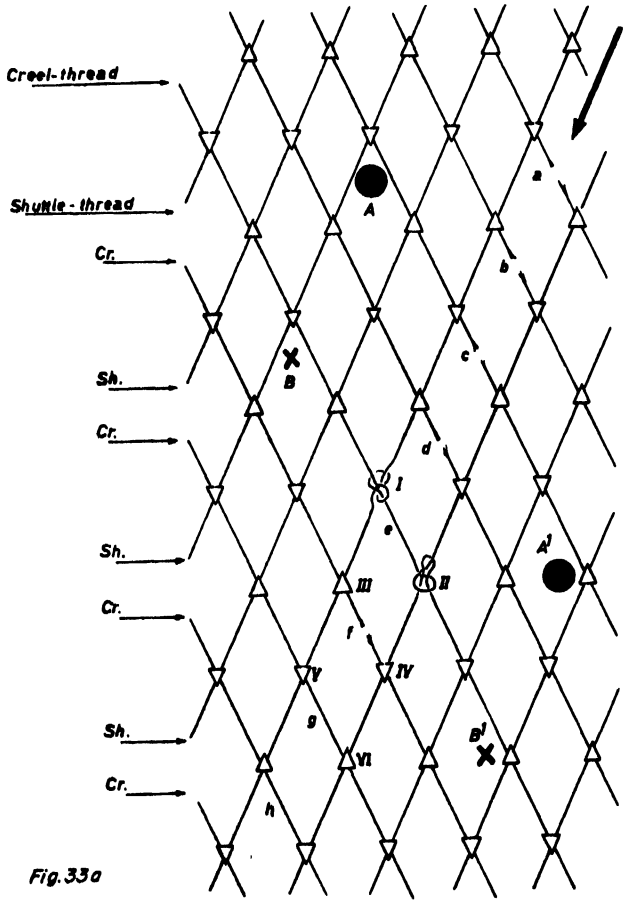


Fig. 33a. Preparation of net sample for the determination of net strength.

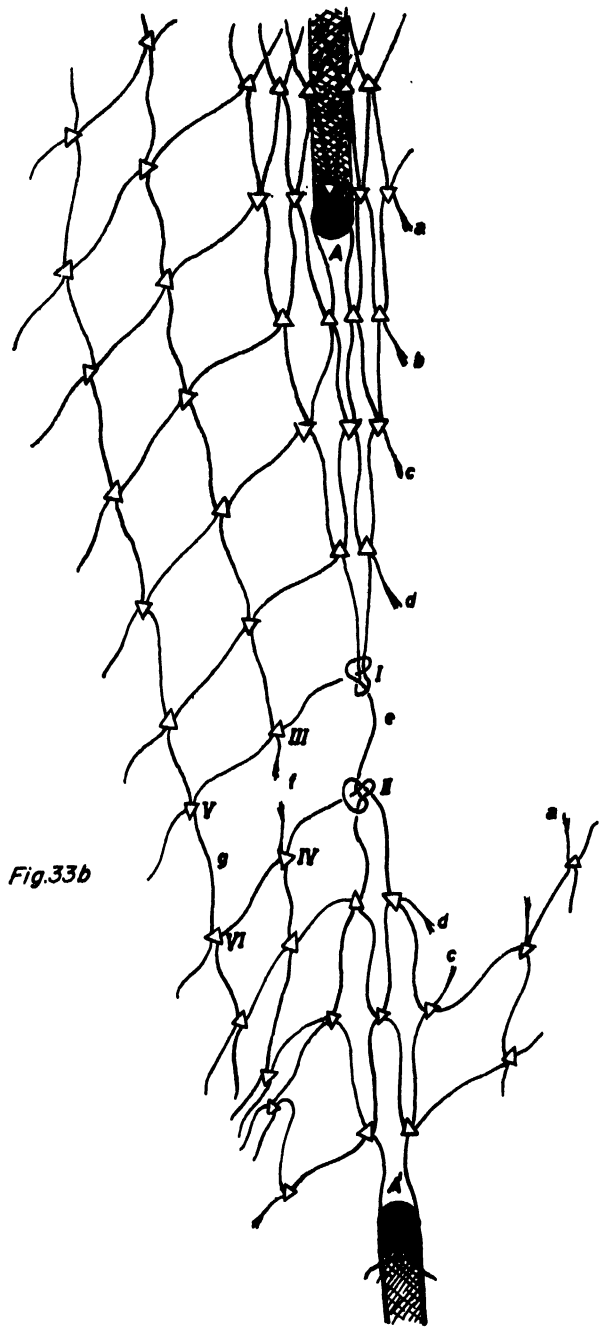


Fig. 33b. Way of hooking a net sample onto the dynamometer for determining the net strength.

Two methods for netting strength have been proposed, the first applying the load to a single mesh, and the second applying the load to several meshes at once.

It is not always true that the measurement of mesh strength by Proposal (a) in Section 19 is preferred to the following proposal by van Wijngaarden even though the former can be conducted more easily and requires less material, because the latter permits a better study of knot stability (see Section 20) at the same time.

Proposal (a): [103] For the test, machine-made netting is cut in the manner shown in Fig. 33a. The twines from the creel on the netting machine must be distinguished from the twines from the shuttle. The twine from the shuttle makes the knot whereas the twine from the creel only forms the loops. The mesh bars are cut at a, b, c, and d in Fig 33a, but not at e, yet again at f. The netting is stressed in a strength-testing machine, the same as is used for measuring mesh strength, by the upper hook A and the lower hook A^1, shown in Fig. 33b.

The netting strength is that force in kg which breaks the netting at the uncut mesh bar shown as e in Fig 33a and b. The speed of the loading jaw traverse · equals one per cent of the initial specimen length per second.

For the subsequent test break, the netting is mounted on the testing machine with the hooks in meshes B and B^1 (Fig. 33a) and the mesh bar at h is cut.

This test cannot be conducted if the knots slip.

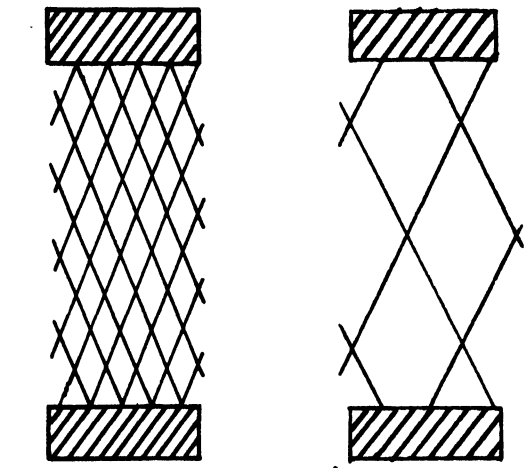


Fig.34

Proposal (b):[104] For measuring netting strength, strips of netting four meshes (five knots) wide are cut in both the lengthwise and breadthwise (depthwise) directions from the net, and nine bars of the strip are fastened between the clamps of a suitable tensile tester for each test break (see Fig. 34a). The initial distance between the clamps should be no more than 20 cm and the speed of the loading-clamp traverse should be 15-30 cm per minute. If necessary, fewer meshes in breadth or in length may be taken to accommodate the limitations of the tester, but in such cases the size of the specimen must be reported (see Fig. 34b).

At least 10 test breaks should be conducted, and the average is reported as the test strength.

The way in which the specimen is mounted in the clamps on the tester is of utmost importance. The knots, being thicker than the twine, can be broken by the pressure cutting the twine in the knot if the knots are caught between the faces of the clamps. Also, it is difficult to mount the specimen in such a way that the load is equally distributed among all the mesh bars across the sample. Therefore, Carrothers [105] threads a rod through the meshes on the upper edge of the specimen and another rod through the meshes on the lower edge, and hooks these rods onto the strength-testing machine so that the machine pulls these rods one from the other until the specimen breaks. For such mounting, the test specimen must be a whole number of meshes wide, not, for example, $1\frac{1}{2}$ meshes as shown in Fig. 34b.

Rending strength:[106] The specimen may be cut from the netting either lengthwise or breadthwise (depthwise) as shown in Fig. 35. The specimen should be larger than ten knots = nine meshes square. A cut about 15 cm long is made into the specimen so that five knots = four meshes remain uncut. The parts marked A and B in Fig 35 are pulled apart by the strength-testing machine. The initial distance between the clamps is 10 cm and the speed of loading jaw traverse is 15-30 cm per minute. The rending strength is that force which is required to tear the sample for five knots or more. At least 10 test breaks should be made.

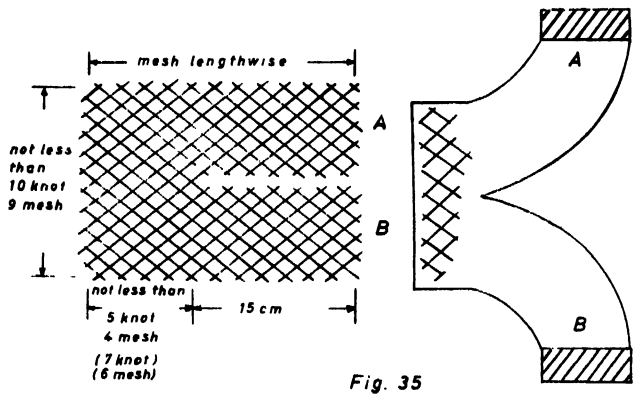


Fig. 35

Frictional strength in minnow netting:[107] The procedure for testing the strength of woven minnow netting is different from that for other types of netting. The test specimen is cut 30 cm long in the direction of the warp by 10 cm wide in the direction of the woof or filling. The specimen is prepared as shown in Fig. 36. At the upper end of the specimen, all but the central warp are cut short and only the central warp is attached to the upper clamp of the strength-testing machine. At the lower end of the specimen, the central warp is cut short and all the warps but it are attached to the lower clamp. The number of woof or filling threads is limited to 15. The specimen is pulled apart at 15-30 cm per min and the force required to pull the central warp out of the specimen is measured. At least 10 tests are made. This procedure can be applied only to minnow netting which has been treated with a resin or some such similar bonding material.

[103] van Wijngaarden, J. K.: Method for determining the tear resistance of nets, the so-called net strength. N.V. Research, Arnhem, Preevenverslag, 1959.

[104] Japanese Industrial Standard (draft) J.I.S.L., 1958 (5-9).

[105] Modern Fishing Gear of the World, p. 72, 1959.

[106] Japanese Industrial Standard (draft) J.I.S.L., 1958 (5-11).

[107] Japanese Industrial Standard (draft) J.I.S.L., 1958 (5-12).

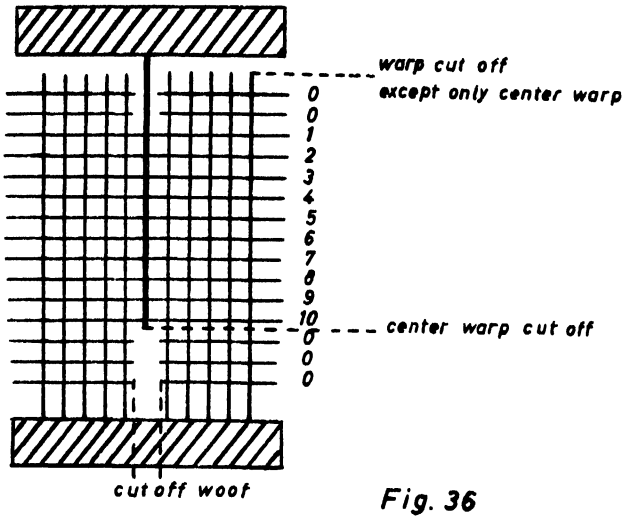


Fig. 36

(20) Knot stability

When netting materials of synthetic fibres came into use, the question of knot stability or knot constancy arose. The term "knot strength" is sometimes used wrongly in this context. Knot stability is the ability of the knot to retain its original form, both resisting inversion into another form without twine slip and resisting loosening with resulting twine slip but without inversion. Knot stability is a prerequisite for constant mesh size in a fishing net. The following test methods refer to the resistance of the knot to inversion, of the twine to slipping in the knot, and of the knot to loosening.

Inversion resistance: When netting is made with the weaver's knot, it is possible that the loop C-D (Fig. 37) does not fall correctly when the knot is tightened so that it forms an insecure knot with the mesh of the preceding row. This insecure knot can also be formed from a proper weaver's knot if the mesh legs A and B are pulled apart strongly while legs C and D remain slack. A similar insecure knot can also be formed in the same way, and usually more easily, from a reef or square knot. It can be seen, as shown for the weaver's knot in Fig. 37, that, in these insecure knots, the netting material C-D can readily slip on netting material A-B.

Proposal (a):[108] This procedure is based on the fact that the knot can be inverted into a slip knot as described above. The legs A and B (Fig. 37) are stretched between the clamps of the strength-testing machine while the legs C and D remain free. The force at which the inversion of the knot occurs is measured and may be reported in kg or as a per cent of the knot strength.

[108] van Wijngaarden, J. K.: Testing methods for net twines and nets. Modern Fishing Gear of the World, pp. 75-81, 1957.

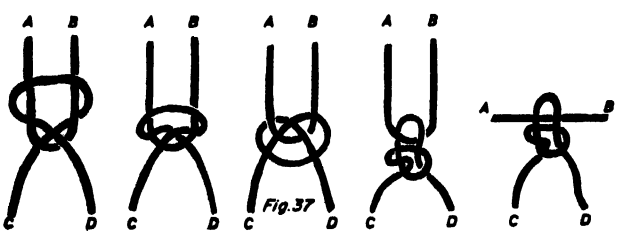


Fig. 37

When the knots for this test have not been cut from netting but have been formed by hand, the force by which the knots are tightened is important. To minimise the effect of this variable, the knots should be pulled together by a force equal to about 20 per cent of the knot strength.

Proposal (b):[109] For this test, several weaver's knots C and D are tied in the netting material A and B as shown in the first drawing of Fig. 37 and Fig. 38. The material A and B is loaded by a series of frequent jerks in an effort to invert the knots. The arrangement is shown in Fig. 38.

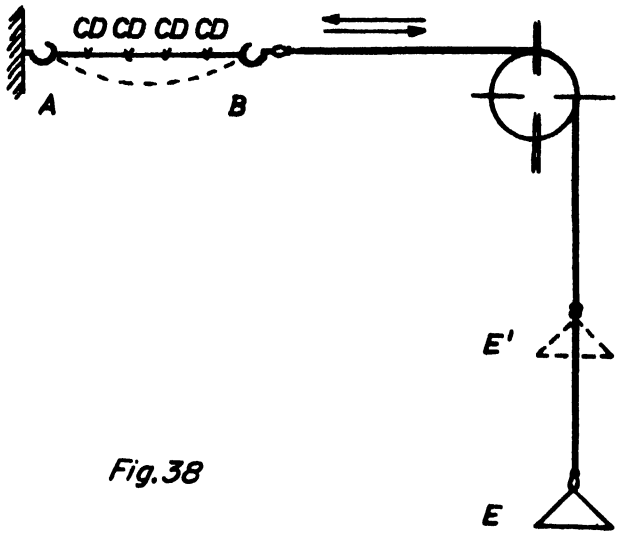


Fig. 38

The knotted test specimen is stretched horizontally so that the resulting deformation of the knots may be better observed. The loading mass E equals that of the 500-m weight. For the test, the mass is lifted 50 cm and is allowed to fall every two seconds, thereby jerking the specimen.

[109] Treschev, A. J.: Laboratory of Fishing Technique. Research Institute of Marine Fisheries and Oceanography, Moscow.

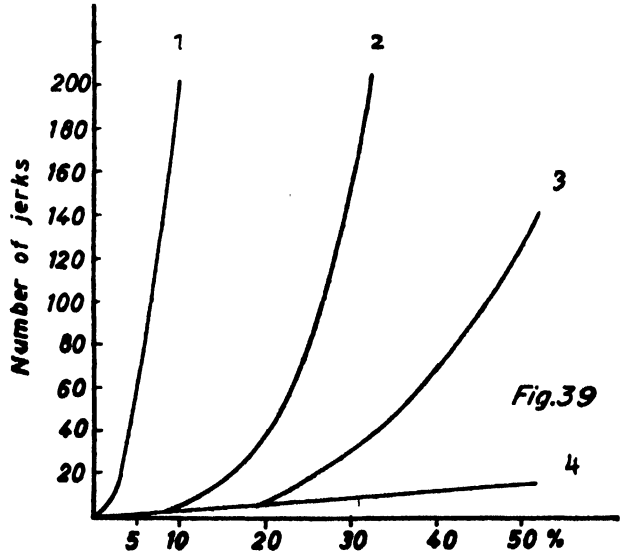


Fig. 39

Fig. 39. Tightening force of knots in per cent of the cord strength: (1) treated cotton knots: (2) untreated cotton knots: (3) Capron knots fixed at temperature 100°C: (4) Untreated cotton flap knots.

The number of jerks required to invert the knot is taken as the measure of its stability or resistance to inversion. This, in turn, is largely dependent on the force by which the knots are tightened, usually taken as a per cent of the twine strength as shown in Fig. 39.

Proposal (c):[110] By this proposal, the inversion resistance discussed above and the knot-slip resistance mentioned below are both measured while testing for mesh strength by Proposal (a) for mesh strength in Section 19 above. The strength tester is the usual pendulum type with an automatic load-elongation recorder and reverse stop-pawls on the pendulum. The test mesh is mounted on the tester as shown in Fig. 30 with the pins a known distance apart. Thus, the distance for which the recorded line follows the elongation axis (load = 0) when added to the initial spacing of the pins, gives the mesh opening under zero load. If one of the knots inverts, this shows as a short distance on the recorded line which is parallel to the elongation axis (recorded load = constant = invertion resistance). Twine slip in a knot also shows as a straight portion in the recorded line parallel to the elongasion axis, but this is usually longer than the knot inversion indication (recorded load=constant=knot-slip resistance). In any one mesh, only one knot can invert and only two can slip. Therefore, it is necessary to watch only three knots during test to distinguish inversion from slip for the record. For this test, none of these knots should touch either of the pulling pins. If the mesh eventually breaks, the inversion resistance and the knot-slip resistance may be reported as a per cent of the mesh strength. Thus, by this one procedure, as many as four different properties may be measured. This procedure has the further advantage that variations resulting from variously tightened hand-tied knots are avoided by using netting meshes.

Knot-slip resistance:[111] Slipping can also occur without any deformation of the knot. If the knot is stressed from one side only, that leg can slip through the knot without the knot becoming broken.

For measuring slippage in a knot, the legs C and D vs. A (Fig. 40) are stressed in the strength-testing machine. The force which causes 5-cm of the free leg B to slip out of the knot is reported. (The 5-cm length is used only with knots tied specifically for the test.) In this test, the angle between legs C and D should be 0°, and the rate of loading-clamp traverse should be one per cent of the initial separation per second. Manually tied knots should be tightened for 10 sec, 5 min before the test, by a force equal to 20 per cent of the knot strength.

The knot-slip resistance is reported as that force, expressed in kg or as a per cent of the knot strength, at which slipping first occurs for more than one second. Shorter jerks which result from tightening of the stressed knot are ignored. Knot-slip can be seen particularly well if the extension of the specimen is recorded autographically at the time of testing. Then the following may be observed (Fig. 41):

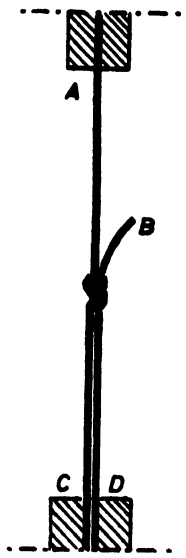


Fig. 40

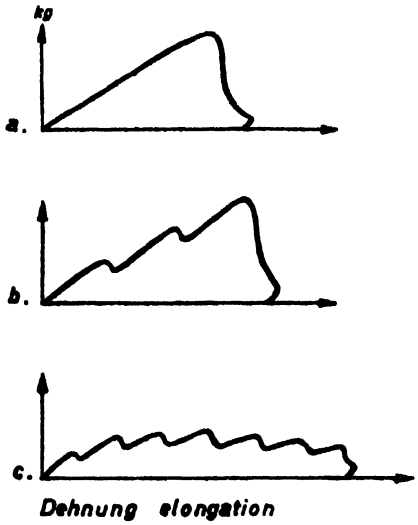


Fig. 41

(a) The knot does not slip but the specimen is extended and breaks in the knot (Fig. 41a).

(b) After a certain load has been applied the knot slips in a jerking manner. However, the material breaks before the free leg B has slipped completely out of the knot (Fig. 41b).

(c) A more or less steady slipping occurs until the free leg B has slipped completely out of the knot (Fig. 41c).

At least 10 tests are carried out. Knot-slip resistance may also be evaluated by reporting the frequencies at which the above alternatives occur as per cents of the total number of tests.[112]

Loosening resistance: For this, the knots are placed in a rotating box and their opening-up is observed.

Proposal (a):[113] For testing loosening resistance, knots are tied between pieces of the netting material about 20-cm (8 in) long. The knots are tightened by fastening a weight equal to 1 g per five resultant twine tex (200 m weight) to both ends of the same twine and allowing the weight to fall 20 cm before the knot takes the load.

Five of the knots thus formed are placed in a rotating wooden box (20×30×20 cm) which turns at 60 revolutions per min (Fig. 42). The box is stopped at regular time intervals and the number of knots which have become loosened is counted.

[110] Carrothers, P. J. G.: Fisheries Research Board of Canada, St. Andrews, N.B., Canada.

[111] van Wijngaarden, J. K.: Testing methods for net twines and nets. Modern Fishing Gear of the World, pp. 75-81, 1957. Also, Methods of testing net cord and nets. Rayon Revue 11, pp. 146-160, 1957.

[112] v. Brandt, A.: Zür Knotenkonstanz von Fischnetzen. Archiv für Fischereiwissenschaft, 9, pp. 244-265, 1958.

[113] von Wijngaarden, J. K.: Testing methods for net twines and nets, etc. Modern Fishing Gear of the World, pp. 85-91, 1959. Also, Methods of testing net cords and nets. Rayon Revue 11, pp. 146-160, 1957.

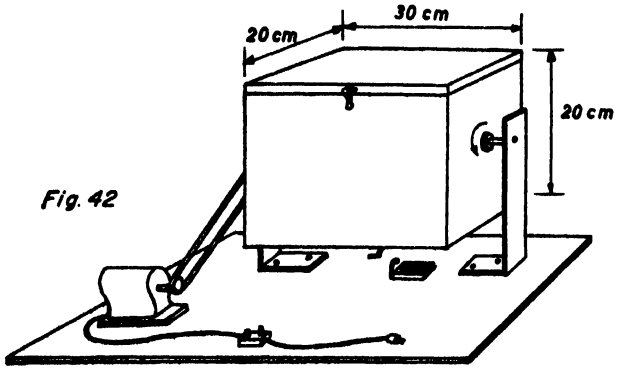


Fig. 42

Proposal (b):[114] Knots from netting or knots formed under a known tension from netting twine are cut in such a way that their legs are 1·5-cm ($\frac{4}{8}$ in) long. For synthetic netting twines the twine ends are fused and for natural fibre netting twines the twine ends are cemented to prevent them from unravelling.

At least 10 of these knots are put into a rubber-lined box which rotates at 60 turns per min. A small rubber cylinder is also placed in the box. The box is made of metal, to permit wet tests, and is $15 \times 10 \times 10$ cm. After 10, 20, and 30 min, the number of knots which have become loosened during each period is counted, and is reported as a per cent of the total number of specimens.

(21) Weight of netting

The dry weight of uncut netting is of interest for commercial purposes. However, the wet weight is also of interest because the netting is usually wet when lifted through the air during fishing operations. Finally, the buoyed weight of netting while still in the water is of interest. The manner used for stating the weight of netting varies because of the different ways in which the measurements are made, e.g., length may be stated as the number of conventional length units or as the number of meshes (see Section 18) and weight may be stated in metric or in other units.

Dry weight of netting: stated exactly, the weight of netting for commercial purposes is not its actual, air-dry weight, but is its bone-dry weight plus a standard moisture content. The corrected weight of the netting can be computed from the following formula:[115]

$$\text{Standard weight} = \text{measured weight} \times \frac{100 + Rc}{100 + R}$$

where R = measured moisture content (%)
Rc = standard moisture content (%).

Standard moisture contents for various textile materials may be different in different countries, and this should be recognised when "official" moisture ratios are quoted. Standard moisture contents for natural fibres are all higher than the contents usually found actually to exist.

The actual moisture content is found by drying the specimen at 105-110°C until its weight is constant. This determination cannot be made if the thermoplasticity of synthetic fibres is such that they must be dried below 60°C.

The following is an official moisture content for various textile fibres:

Natural fibres		Synthetic fibres	
cotton	8·5%	polyamide	4·5%
flax	12	polyester	0·4
hemp	12	vinyl chloride	0
ramie	12	polyvinyl alcohol	5·0
sisal	12		
manila	12		

Proposal (a):[116] The proposal is based on the statement of the length of the netting in metres and of its breadth (depth) in the number of meshes. If the weight (c) in kg is known for a piece of netting of a given twine number and mesh size, 100 m long by 100 meshes broad (deep), the weight of any other piece of the same style of netting may be estimated from the formula:

$$\text{Weight (kg)} = \frac{\text{length} \times \text{breadth (depth)} \times \text{c.}}{100 \times 100}$$

Values for the constant c are given in Tables 1, 2, 3, and 4. They are the weights of pieces of netting, 100 m long when fully extended by 100 meshes broad (deep),[117] which have been measured by the netting manufacturers under prevailing conditions of temperature and humidity, not in conditioned rooms with the standard atmosphere. Thus, these values may vary between different factories. Also, differences in these weights may be caused by the knots being more or less strongly tightened.

These tables give the values for air-dry netting made with the single weaver's knot using medium-laid twines of cotton (Tables 1 and 2), flax (Table 3), or hemp (Table 4). Of course, these tables are valid only in a climate similar to that of Central Europe, hence they are presented only as an example. These lists of data may be examined further and presented graphically. The resulting curves should not have a discontinuity. If, for a given twine size, the weights for pieces of netting of only a few mesh sizes are known, the weights for intermediate mesh sizes may then be determined by graphical interpolation.

In these tables, the mesh sizes have been reported as the distance between the centres of neighbouring knots (mesh size = mesh-side length = $\frac{1}{2}$ mesh length).

Proposal (b):[118] This proposal is based on the statement of the length of the netting in fathoms (1 fm = 6 ft = 1·83 m) and of its breadth (depth) in the number of meshes. The weight is estimated in lb.

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[114] Stutz, H.: Lateral strength and knot-firmness of synthetic twines for fishing purposes. Modern Fishing Gear of the World, pp. 87-92, 1959. Also, v. Brandt, A.: Zür Knotenkonstanz von Fischnetzen. Archiv für Fischereiwissenschaft 9, pp. 244-265, 1958.

[115] Japanese Industrial Standard (draft) J.I.S.L., 1958 (2-12).

[116] v. Brandt, A.: Arbeitsmethoden der Netzforschung, Stuttgart, p. 101, 1947.

[117] Schmidt, K., and Amwand, K., have also published constants for estimating the weights of netting which is not fully extended but is hung to various ratios: Tabellen zur Gewichtsberechnung von Baumwollnetzen unter Berücksichtigung eines Einstellungsverhältnisses. Deutsche Fischerei Zeitung 5, pp. 100-104, 1958.

[118] Fisheries Research Board of Canada, Technological Station, Vancouver, B.C., Canada.

Table 1

Nm	5	6	8	10	12	14	16 mm
270/6				0,64			
250/6	1,00	0,90	0,82	0,76	0,73	0,71	0,70
200/6	1,20	1,10	1,00	0,90	0,88	0,86	0,82
160/6	1,45	1,35	1,20	1,10	1,07	1,04	1,00
140/6	1,95	1,80	1,60	1,35	1,33	1,31	1,29
100/6	2,15	2,00	1,87	1,80	1,76	1,73	1,68
100/9	3,80	3,50	3,10	2,80	2,70	2,60	2,54
85/6	2,95	2,80	2,45	2,20	2,14	2,08	2,03
85/9	3,90	3,80	3,74	3,50	3,40	3,33	3,25
70/6		3,60	3,20	2,90	2,84	2,75	2,65
70/9		5,20	4,70	4,10	4,00	3,90	3,80

Nm	18	20	25	30	40	50 mm
270/6		0,54		0,52	0,50	
250/6	0,69	0,69	0,67	0,65	0,62	
200/6	0,80	0,78	0,74	0,73	0,72	
160/6	0,98	0,96	0,94	0,92		
140/6	1,27	1,25	1,20	1,15		
100/6	1,67	1,65	1,60	1,55	1,50	
100/9	2,52	2,50	2,45	2,40	2,30	
85/6	1,98	1,95	1,90	1,88	1,85	
85/9	3,17	3,10	2,95	2,90	2,82	2,80
70/6	2,57	2,50	2,45	2,40	2,30	
70/9	3,70	3,65	3,60	3,55	3,50	

Table 2

Nm	6	8	10	12	14	16	18	20	22	25	30	35	40	45 mm
50/9	7,0	6,4	5,8	5,6	5,4	5,3	5,1	5,0	4,9	4,8	4,7	4,6	4,5	
50/12	10,0	8,7	8,2	7,7	7,3	7,0	6,8	6,7	6,6	6,5	6,3	6,2	6,1	6,0
50/15	14,0	12,0	10,8	10,2	9,6	9,0	8,9	8,8	8,6	8,5	8,0	7,9	7,7	7,5
50/18		14,0	13,4	12,5	12,0	11,7	11,2	11,0	10,8	10,6	10,0	9,8	9,6	9,4
50/21		18,0	16,3	15,5	14,7	13,9	13,5	13,2	13,0	12,6	12,2	11,8	11,5	
20/6	14,0	12,0	10,9	10,4	9,8	9,3	8,9	8,7	8,5	8,3	7,8	7,7	7,6	
20/9		21,0	17,6	17,1	16,3	15,3	14,7	14,0	13,8	13,4	12,7	12,5	12,2	
20/12		27,1	26,0	24,5	23,5	22,5	21,7	20,4	20,1	19,3	17,9	17,7	16,7	
20/15			34,2	31,6	30,0	28,8	27,8	27,0	26,0	25,3	24,0	22,9	21,6	
20/18			42,0	39,6	37,9	35,9	34,8	34,4	33,6	32,3	30,7	29,3	27,5	

Nm	18	20	25	30	35	40	50	60	70	80	100 mm
20/21	40	39	37	36	34	31	30	29	28,5	28	27
20/24		47	44	42	40	38,5	36	34	33,5	33	32
20/27		55	50	48	46	45	42	40	39	38	37
20/30		60	57	55	53	51	46,5				
20/36		74	70	66	63	59	57	54			
20/42		88	82	77	73	71	67	65			
20/48		102	95	88	83,5	81	76,5	74			

Table 3

Nm	10	12	15	20	22	25	30	35	40	45	50	60	70 mm
18/6	10,6	10,0	9,6	8,5	8,3	8,2	7,9	7,7	7,6	7,5	7,4		
18/9	16,2	15,4	13,9	12,8	12,7	12,6	11,8	11,6	11,0	10,8	10,7		
18/12	23,0	21,7	20,4	19,0	18,2	17,5	17,2	16,4	16,1	16,0	15,8		
16/4	7,9	7,5	7,0	6,3	6,2	6,1	6,0	5,9	5,8	5,7	5,6		
16/6	11,9	11,5	10,8	9,4	9,3	9,2	9,1	8,9	8,7				
16/8	16,5	15,5	14,5	13,2	12,8	12,3	12,0	11,8	11,6	11,4	11,2		
16/12	28,0	26,0	23,9	21,2	20,5	20,0	19,2	19,1	18,7	18,4	18,2		
16/15	40,0	38,0	33,5	29,5	28,5	27,5	25,5	24,7	24,0	23,7	23,3	23,0	22,6
16/18	52,0	47,5	42,5	37,5	36,0	34,5	32,0	30,6	30,4	29,9	28,4	27,6	26,2
10/6	19,5	18,0	16,4	15,0	14,7	14,6	14,3	14,1	13,8	13,2	13,0		
10/12	58,6	53,0	46,9	41,2	40,0	38,0	37,6	33,3	31,0	29,1	27,6	25,8	

Table 4

Nm	6	8	10	12	15	18	20	22	25 mm
70/6	3,0	2,8	2,6	2,4	2,2	2,2	2,1	2,1	2,1
70/9	4,0	3,8	3,7	3,5	3,4	3,4	3,3	3,3	3,2
75/9			3,6		3,3		3,2		
85/6	2,2	2,2	2,1	2,0	1,9	1,8	1,8	1,8	1,8
85/9	3,1	3,1	3,0	2,9	2,8	2,8	2,7	2,7	2,6
100/6	1,8	1,8	1,7	1,7	1,6	1,6	1,5	1,5	1,5
100/9	2,7	2,7	2,6	2,5	2,4	2,3	2,2	2,2	2,2
120/6			1,5		1,4		1,3		
120/9			2,2		2,0		1,9		
140/6	1,5	1,4	1,3	1,2	1,1	1,1	1,1	1,1	1,1
160/6	1,5	1,08	1,04	0,99	0,95	0,92	0,89	0,89	0,89
200/6	0,8	0,79	0,78	0,77	0,76	0,73	0,70	0,70	0,69
240/6			0,82		0,70		0,68		
270/6			0,64		0,57		0,54		

Nm	28	30	32	34	36	38	40	45	50 mm
70/6	2,1	2,1	2,0	2,0	2,0	2,0	2,0	1,9	1,9
70/9	3,2	3,1	3,1	3,1	3,1	3,1	3,1	3,0	3,0
75/9		2,8					2,8		
85/6	1,7	1,7	1,7	1,7	1,7	1,7	1,6	1,6	1,6
85/9	2,6	2,6	2,6	2,5	2,5	2,4	2,3	2,2	2,2
100/6	1,5	1,5	1,4	1,4	1,4	1,4	1,3	1,3	1,3
100/9	2,2	2,2	2,2	2,2	2,2	2,2	2,1	2,1	2,1
120/6		1,2					1,2		
120/9		1,8					1,7		
140/6	1,1	1,0	1,0	1,0	1,0	1,0	1,0	1,0	1,0
160/6	0,89	0,88	0,88	0,88	0,88	0,88	0,88	0,85	0,80
200/6	0,68	0,67	0,66	0,66	0,66	0,65	0,64	0,64	0,64
240/6		0,65					0,63		
270/6		0,52					0,50		

(23) Visibility

The assessment of the absolute visibility of netting, particularly of gillnets under different conditions, or the study of whether or not the netting blends with the surroundings in the water, can be achieved by direct observation as by a SCUBA diver or with the help of a bathyscaphe or television. As a record is usually required for comparisons, photography is used. Probably these visibility studies should be made with natural light rather than with artificial light, and the turbidity of the water as measured by oceanographers should be reported with the test results.

The visibility can be varied by lowering the netting and the camera together to the desired depth and photographing by remote shutter release. In this instance it is proposed to study only pieces of netting. These are stretched on a frame and are mounted with the camera on a base as shown in Fig. 44.[126]

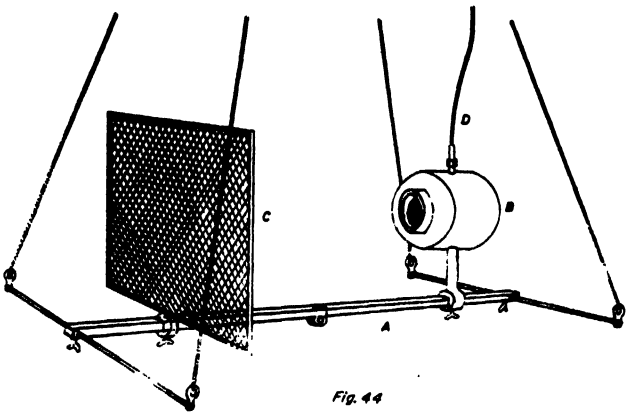

Fig. 44

The apparatus consists of a base bar A, about 1·5 m long, on which the waterproof case with the camera, B, and the frame carrying the netting under study, C, have been fixed. The frame takes a piece of netting 50 × 50 cm which may be interchanged with similar pieces of different types of netting for comparison.

The camera should preferably be a model with automatic winding. In this way, several photographs can be made in sequence with the help of cable D without removing the camera from the water. It should be noted that, for example, at an actual distance of 1·3 m between the netting and the camera, the camera should be focused at 1·0 m because of the higher index of refraction in the water. At an actual distance of 1·2 m an optical distance of 0·9 m should be used. Preliminary test photographs should be taken to determine the exposure, particularly if colour pictures are being taken.[127]

[126] Ulrich, B.: Ein neues Gebiet für den Robot-Fernauslöser. Neue Fotolinie, No. 6, pp. 15-19, 1951.

[127] Park, Y. J.: Visibility of webbing dyed with several kinds of colours under the ocean. Bull. of Fisheries College, Pusan National University, Vol. VI, pp. 7-10, 1962. Describes measuring the visibility of netting by fastening pieces of netting to a frame and by carefully and slowly lowering the whole into the water until the observer cannot obviously recognise the netting through a water glass. The depth in cm is taken as a measure of the visibility of the netting under test.

(24) Hydrodynamic resistance of netting

Since the hydrodynamic resistance of netting cannot readily be estimated from the towing resistance of towed gear, the netting can be stretched on a frame for measuring this property. Such measurements can conveniently be made in a tank in which other objects, such as ship models, can also be tested. The netting is towed at different speeds, preferably those at which full-scale gear is dragged, expressed in nautical miles per hour (knots) or metres per second (Fig. 45). One square metre of netting has been used for such tests.[128] The resistance of the frame alone is measured separately, and this is subtracted from the resistance of the mounted netting.

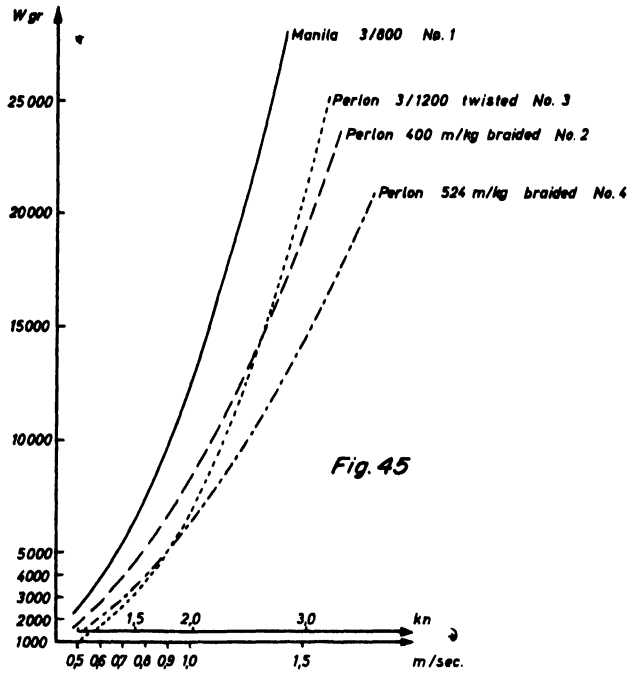

Fig. 45

As the use of ship-model tanks is very expensive, simpler makeshift apparatus has been used.[129] Fig. 46

[128] Institut für Netzforschung, Hamburg. Also, Deutsche Seiler Zeitung 79, pp. 146-197, 1960.

[129] Miyamoto, H.: Hydrodynamic resistance of a plane net: International Shipbuilding Progress 2, pp. 291-295, 1955. Nomura, M., and Mori, K.: Resistance of a plane net against flow of water III—Effect of kind of fibres on the resistance of net. Bull. Japanese Soc. Sc. Fish., Vol. 21, pp. 1110-1113, 1956.

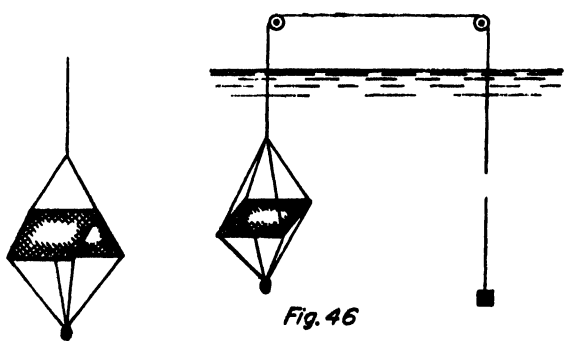
Fig. 46

represents the required arrangement. A piece of netting is stretched on a metal or wooden frame, loaded by a weight and balanced by a counter-weight. In this the netting may be set at right angles to the direction of motion or at any other desired angle to it. The frame is allowed to sink through the water under a known force both with and without the netting to be tested. The resistance of the netting to motion through the water may then be computed either from the times required for the frame to travel a certain distance or from the distances travelled by the frame in a certain time.

DISCUSSION

Dr. A. von Brandt (Germany) Rapporteur: There is no doubt that clear definitions are the basis of all our discussions. Just as we need a numbering system, we also need an agreement on testing methods for the properties of materials. It was therefore a very important achievement that, at the first International Fishing Gear Congress, a working group was set up to advise on and recommend standard methods of testing net materials. To help that working group scientists of Canada, Denmark, France, West and East Germany, Japan, the Netherlands and the USSR gave co-operation in providing information about the methods actually used in their country for testing netting twine and netting. The group had to limit its work to these two items, but there was no doubt that agreement was also needed on testing methods for ropes and lines as used in fisheries as well as an agreement on methods of testing the different types of fishing gear either in model or full scale.

The version of the work on testing netting twine and netting now presented by P. J. G. Carrothers (Canada) and myself should be considered as a draft and not as a final form. It does, however, review the situation as it is now and we hope it will help all who want to begin testing materials for fishing gear.

In the meantime, national working groups for definitions and testing methods have been set up in different countries. Furthermore, some international groups have discussed special items, e.g., the International Council for the Exploration of the Sea and the International Council for Northwest Atlantic Fisheries have discussed methods for testing mesh size; and a new international working group on biological deterioration of material, including the rotting of fish nets in water, was established two weeks ago by the Organisation for Economic Co-operation and Development in Paris.

Standardisation, however, could not be effected by these bodies but only by the International Organisation for Standardisation, ISO, in London. This organisation had set up last year a special sub-committee for textile products as used for fishing nets and the second meeting of this sub-committee was held in London recently. Actually many fishery experts in this field were members of this ISO sub-committee and they were in a position to endeavour to make certain that ISO would decide on standards which were in accordance with the wishes of fisheries as well as of the textile industry.

In order to rationalise and to avoid duplication of effort, I suggest the FAO working committee for standardisation of testing methods set up during the First Gear Congress be dismissed and its functions transferred to that sub-committee of the International Organisation for Standardisation.

Mr. A. F. B. Nall (UK) a Member of the British Standards Institution, outlined the position of ISO. It was the recognised body for international work on standards of quality, performance, size or terminology. It was set up by the United Nations during the period 1941-1948 and it worked through the national standards organisation of member countries. There were over 100 technical committees belonging to ISO and among them was Committee No. 38 dealing with textiles. This comprised representatives of 41 countries from all parts of the world. There were specialised sub-committees dealing with textile products for fishing needs. Germany was responsible for the Secretariat of that committee and at the last meeting there were representatives of nine countries present and some of those representatives have been members of the FAO working group. There were strong links between the two bodies in both membership and purposes.

Netting Twines of Polypropylene and Polyamide Compared

by
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Abstract
This paper concerns experiments to date conducted with polypropylene, a synthetic fibre developed in 1954. Properties of polypropylene netting twines which were tested include breaking strength dry and wet, knot breaking strength, extensibility and influence of twine construction. A rather complete comparison is made between polypropylene twines and polyamide twines. It is pointed out that at the first International Fishing Gear Congress the authors generally judged the efficiency of the synthetic net material by comparing their properties with those of natural fibre twines. At the present time, however, new net materials have to compete with high-class synthetic twines, especially polyamide. Comparisons of new synthetic twines with twines of natural fibres rather than with established synthetic twines cause little interest among members of the fishing industry. Comparative tests between polypropylene twines and polyamide twines reported on in this paper include breaking strength and R tex, breaking strength and diameter, abrasion resistance, extensibility and elasticity. A résumé is given of actual field work undertaken by other researchers on polypropylene fishing nets in gillnetting for salmon and cod and in bottom trawl fishing. All sections of this paper are thoroughly supplemented with graphs and tables.

Fils et filets de polypropylène et polyamide comparaison de leurs Proprietes

Résumé
La communication traite des expériences conduites jusqu'à ce jour sur le polypropylène, une fibre synthétique développée en 1954. Les propriétés des fils de filets polypropylène éprouvées étaient les suivantes: résistance à la rupture à sec, mouillés et noués, extensibilité et influence de la fabrication. Il y est fait une comparaison assez complète des fils de filets polypropylène et polyamide. Alors qu'au Premier Congrès des Engins de Pêche on jugeait l'efficacité des fibres synthétiques en comparant leurs propriétés avec celles des fils en fibres naturelles, aujourd'hui par contre, les nouveaux matéraux de filets doivent être comparés avec des fibres synthétiques supérieures et spécialement, le polyamide. La comparaison des nouveaux fils synthétiques avec des fils en fibres naturelles n'a plus aucun intérêt pour l'industrie des pêches. Les épreuves comparatives entre fils en polypropylène et fils en polyamide mentionnées dans cette communication ont trait à la force de rupture et la grosseur en R tex, la force à la rupture et le diamètre, la résistance à l'abrasion, l'extensibilité et l'élasticité. Un résumé des essais actuels entrepris par les chercheurs sur des filets en polypropylène dans la pêche au saumon, au cabillaud et dans le chalutage de fond est compris dans cette étude. Toutes les parties de cette documentation sont largement complétées par des graphiques et des tableaux.

Hilos para redes hechas de propileno y poliamido—Comparación de sus propiedades

Extracto
Alude esta ponencia a los experimentos realizados hasta ahora con polipropileno, una fibra sintética descubierta en 1954. Entre las propiedades de los hilos para redes de polipropileno se ensayaron la resistencia a la rotura estando húmedos y secos, resistencia a la rotura del nudo, estiramiento y efecto de la manera de fabricar el hilo. Se hace una comparación bastante completa entre los hilos de polipropileno y los de poliamidos. Se menciona que en el Primer Congreso Internacional de Artes de Pesca los autores, en general, juzgaron la eficacia de un material para redes sintético comparando sus propiedades con las de hilo de fibras naturales. En la actualidad los nuevos materiales para redes tienen que competir con hilos sintéticos de gran calidad, particularmente poliamidos. Las comparaciones de los nuevos hilos sintéticos con los de fibras naturales, más bien que con los hilos sintéticos establecidos, des piertan poco interés entre el personal de la industria pesquera. Los ensayos comparativos entre hilos de polipropileno y de poliamidos de que se informa en esta comunicación comprenden resistencia a la rotura y R tex, resistencia a la rotura y diámetro, resistencia al desgaste, estiramiento y elasticidad. Se hace un resumen de experiencias prácticas realizadas por otros investigadores con redes de polipropileno empleadas para pescar al enmalle salmon y bacalao en los artes de arrastre de fondo. Todas las secciones de esta ponencia están muy bien documentadas con ilustraciones y tablas.

THE introduction of synthetic net materials is certainly one of the three main technological revolutions in modern fishing. Nowadays fishing nets made of polyamide (nylon) are found all over the world. Polyvinyl alcohol nets have also gained great importance in some countries, while the use of polyvinyl chloride, polyvinylidene chloride, polyethylene and polyester for fishing nets has remained more limited. In 1954, a new synthetic fibre, polypropylene, was developed in Italy and is now manufactured in several other countries. The author has tested more than 40 samples of netting twines made of this fibre, ranging in size from fine gillnet twines to thick trawl twines, and originating from Great Britain, Denmark, Italy, Japan and Germany. In this paper only continuous multifilament twines of high fibre quality are considered.

Testing methods

R tex values—i.e., the actual weight in grams of 1,000 m of the netting twine—and runnage in m/kg were calculated from the weight of 10 m of the samples. The values of diameter are average data of 20 single measurements taken on a twine length of 10 m with a dial gauge (Frank).

Twines which were tested in wet condition were immersed in water for one day or, if not enough time was available, for one hour with the wetting agent 'Nekal BX' added.

Breaking strength was tested by a modern electronic recording dynamometer ('Testatron'). The average data are based on 15 to 20 single tests. Two kinds of knots were used for testing the knot breaking strength, the common overhand knot and the English knot (weaver's knot). In the latter case the knot was tied with two pieces of netting twine and the two ends (bars) of each piece, were fixed in one of the two clamps of the testing machine respectively.

For comparing the results of the weaver's knot with those of the overhand knot the former values must be halved. The knot strength efficiency is related to the breaking strength of the unknotted twine in wet condition. The load-elongation curves were recorded by the strength-testing machine. They extend only to a load corresponding to the knot breaking strength.

The elasticity was tested by loading the freely hanging netting twine samples with a weight of 30 per cent of their breaking strength.

Amount of twist (the number of turns per metre of twine), was determined with a twist tester (Frank). With these values (ts/m) the coefficient of twist was calculated by the formula:

$\alpha = \frac{\text{ts/m}}{\text{Nm}}$ where Nm is the metric number of the netting twine (not of the single yarn). The abrasion resistance was tested with the Sander test machine by rubbing the samples (constantly kept wet) against a rough corundum rod under a load of 200 g. The measured value is the number of double friction movements until the twine breaks. At least 30 tests on each sample.

Properties of polypropylene netting twines

The average data for results of most tests are in Tables I and II. The comments are supplementary.

Breaking strength dry and wet—Unlike twines made of polyamide and polyvinyl alcohol but like twines made of polyethylene and polyester, polypropylene twines have practically the same breaking strength wet as dry. In breaking length, polypropylene twines are of the same high quality as polyamide twines with respect to strength. Their tenacity is higher than that of netting twines made of all other groups of synthetic fibres except polyamides.

Knot breaking strength—With twisted twines, the English knot gave better results than the overhand knot. With braided twines, there was no such difference, thus being similar to polyamide twines. Losses in strength by knotting somewhat depend on twine fineness.

Losses in strength by:	English knot	Overhand knot
Finest netting twines (twisted)	24%	30%
Twisted netting twines of medium strength, approximately from R 130 tex to R 500 tex	39%	45%
Thicker netting twines, twisted	50%	53%
Braided trawl twines	49%	49%

Extensibility—Continuous polypropylene twines have a relatively low extension. The form of the load-elongation curves is very remarkable and typical for polypropylene material—Figs. 4, 5 and 6 show they are almost straight.

Influence of twine construction—Physical properties of twines depend on the quality of the fibre but also to a high degree on the twine construction. The single yarns composing the twines described differ in fineness. Most have the relatively low yarn number of 170 or 190 denier and are combined to twines in the form of cabled yarns. Trawl twines numbered 35, 21 and 22 (Table II) are made of a few single yarns with the high yarn number 3,000 denier; 36 is made of a single yarn of 2,000 denier.

Samples 23 to 28, single yarns of equal fineness about 800 denier. Although differences in fibre quality, fineness of single yarns and the number of yarns in the twines may explain some of the variations shown, the influence of the amount of twist is definitely more evident. It is already known from other continuous multifilament materials, that the breaking strength decreases with

Table 1. Netting twines made of continuous Polypropylene

No of testing	1	11	12	13	14	2	15	3	4	5	6	7	8	9	18	19	10	20
Production	A	B	B	B	B	A	C	A	A	A	A	A	A	A	C	C	A	C
No in Denier	190x2	170x3	170x4	170x6	170x9	190x9	190x9	190x12	190x15	190x18	190x24	190x27	190x30	190x36	570x18	570x18	190x60	570x27
Rtex (1000 m-g)	43,5	63,9	83,4	130	189	211	208	284	351	428	547	647	731	921	1243	1272	1453	1974
Runnage, m/kg.	22900	15657	11990	7686	5291	4740	4805	3517	2850	2336	1830	1546	1368	1085	805	786	688	507
Diameter,mm.	0,23	0,33	0,35	0,44	0,52	0,60	0,58	0,73	0,81	0,89	0,99	1,18	1,19	1,38	1,57	1,55	1,72	2,14
Brkg. strength straight,dry,kg.	2,36	3,67	,4,50	7,38	11,21	13,1	11,0	17,4	-	-	30,6	-	38,8	44,5	68,4	66,8	74,3	93,7
straight,wet,kg.	2,35	3,63	4,13	7,43	11,31	12,9	10,8	17,2	-	-	31,7	-	38,6	43,8	67,0	66,5	72,3	92,3
Brkg. strength,wet o/hand knot,kg.	1,76	2,29	3,02	4,14	6,34	6,5	6,1	8,7	10,8	13,4	16,9	19,0	18,2	20,0	32,1	33,2	33,1	41,7
English knot,kg.	3,63	5,07	6,73	9,2	13,1	14,9	14,2	18,5	21,7	28,0	29,8	43,4	40,0	44,7	76,0	-	70,6	94,8
Engl.knot,half kg.	1,82	2,54	3,37	4,6	6,6	7,5	7,1	9,3	10,9	14,0	14,9	21,7	20,0	22,4	38,0	-	35,3	47,4
*Knot strength efficiency. o/hand knot %	74,9	63,1	73,1	55,7	56,1	50,4	56,5	50,6	-	-	53,3	-	47,2	45,7	47,9	49,9	45,8	45,2
Engl,knot,half %	77,7	70,0	81,6	61,9	58,4	58,1	65,7	54,1	-	-	47,0	-	51,8	51,2	56,7	-	48,8	51,4
Breaking length straight,dry,km	54,3	57,4	54,0	56,7	59,3	62,1	52,9	61,3	-	-	55,9	-	53,1	48,3	55,0	52,5	51,1	47,5
straight,wet km	54,0	56,8	49,5	57,1	59,8	61,1	51,9	60,6	-	-	58,0	-	52,8	47,6	53,9	52,3	49,8	46,8
Bkg.length wet o/hand knot, km.	40,5	35,8	36,2	31,8	33,5	30,8	29,3	30,6	30,8	31,3	30,9	29,4	24,9	21,8	25,8	26,1	22,8	21,1
Engl.knot,half km	41,8	39,7	40,4	35,4	34,9	35,5	34,1	32,7	31,0	32,7	27,2	33,7	27,4	24,3	30,6	-	24,3	24,0
Ext. at knot bkg.strength %	-	-	-	12	12	10	11	10	9	10,5	9	11	11.5	15	12	15	14	15,5

* Knot strength efficiency in the Tables I and II relates to straight breaking strength of wet twines.

increasing twist and that extensibility as well as diameter and weight per-unit-length increase. In Table I the samples 2, 3, 4, 5, 6 and 7 are soft laid with an average coefficient of twist of $\alpha = 118$. The samples 8, 9 and 10 are medium laid ($\alpha = 164$ in the average) and therefore have lower breaking lengths and higher extension values.

Table II Trawl twines made of continuous Polypropylene

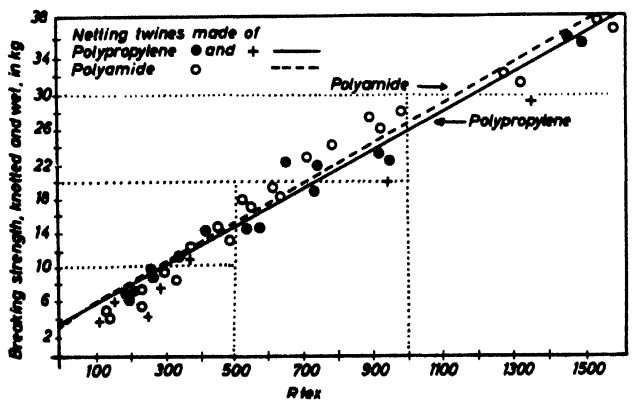
No. of testing	35	36	21	22	23	24	25*	26*	27*	28*
Production	F	F	F	F	A	A	A	A	A	A
Rtex (1,000 meg)	1151	1458	3118	4320	3500	4709	1708	2131	4795	5905
No. of single yarns	3	6	9	12	33	45	18	22	48	60
Munnage, m/kg.	869	686	321	251	286	212	586	469	209	169
Diameter, mm.	1,46	1,64	2,51	2,71	2,61	2,86	-	-	-	-
Bkg. strength										
straight, dry kg.	52,8	59,7	156,7	208,0	164,6	226,5	94,8	114,0	210,0	280,0
straight, wet kg.	52,9	60,4	160,3	210,4	172,1	237,6	94,9	116,4	198,9	282,0
Bkg. strength wet										
o/hand knot, kg.	27,8	33,9	77,5	101,2	73,5	98,7	48,7	57,5	114,5	135,5
Eng. knot, kg.	63,8	76,4	161,0	254,9	160,9	200,2	96,7	115,6	218,3	275,0
Eng. knot, ½kg.	31,9	38,2	80,5	117,5	80,5	100,1	48,4	56,8	109,2	137,5
Knot strength efficiency										
o/hand knot, kg.	52,6	56,1	48,3	48,1	42,7	41,5	51,3	49,7	57,6	47,3
Eng. knot ½kg.	60,3	63,2	50,2	55,8	46,8	42,1	51,0	48,8	54,9	48,8
Bkg. length										
straight, dry km.	45,9	41,0	50,2	48,2	47,0	48,1	55,5	55,5	43,8	47,4
straight, wet km.	45,9	41,4	51,4	48,7	49,2	50,5	55,6	54,6	41,5	47,8
Bkg. length wet										
o/hand knot, km.	24,1	23,3	24,9	23,4	21,0	21,0	28,5	27,2	23,9	22,6
Eng. knot, ½km.	27,7	26,2	25,8	27,2	23,0	21,3	28,3	26,7	22,8	23,3
Extension at knot breaking strength %	-	-	10	11-12	13-15	12-13	9-10	9-11	13-14	11-12

* The twines 25-28 are braided

Comparing polypropylene and polyamide twines

Here the properties of polypropylene twines for fishing nets are compared with those of polyamide twines.

The breaking strength of the two types of twines (see Figs. 1 and 2) is compared wet and knotted with the weaver's knot, because the tests then come nearest to the normal strains of fishing. The knot breaking strengths are compared on the basis of R tex values, Fig. 1 containing those of fine and medium strong twines, Fig. 2 those of heavy twisted and braided trawl twines. The regression-line for polypropylene in Fig. 1 relates to the round black points only and not to the crosses which characterise the breaking strength of twines of lower quality. Both figures show that with the same R tex value both types of fibre have nearly the same breaking strength wet, knotted.



Figs. 1 and 2. R tex values and knot strength of netting twines made of continuous polypropylene compared with those of polyamide.

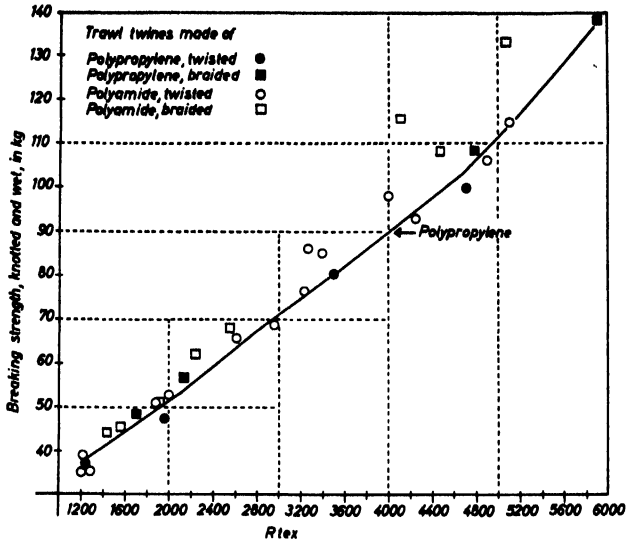


Fig. 2. See caption Fig. 1.

Breaking strength and diameter—Apart from its high tenacity the most remarkable property of polypropylene is its low specific gravity of 0·91 as compared with 1·14 for polyamide. Specific gravity and specific volume being reciprocally proportional, the diameter increases with decreasing density. Polypropylene twines, therefore, must be thicker than polyamide twines of equal weight per-unit-length. Since twines of both fibre types with equal twine number have nearly the same breaking strength, the diameters can also be compared on the basis of the latter property. Fig. 3 shows the result of this comparison. Very thin twines of both fibres do not differ in breaking strength and diameter. With stronger twines those made of polypropylene are on average about 15 to 20 per cent thicker than polyamide twines.

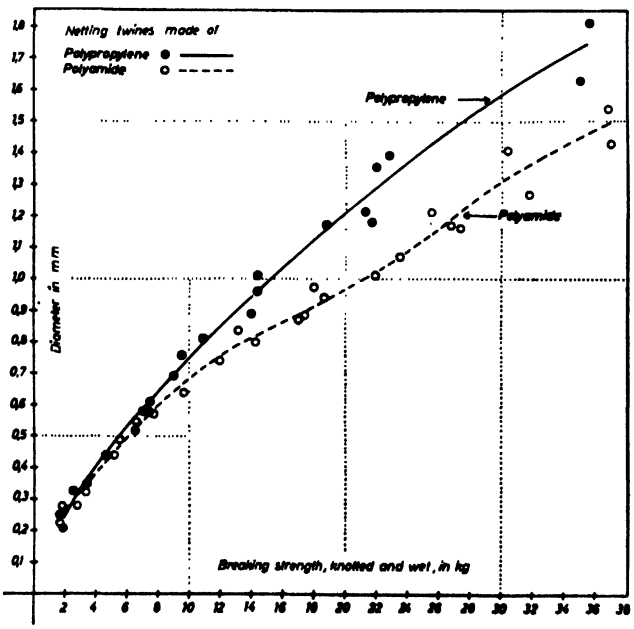


Fig. 3. Knot strength and diameter of fine and medium strong netting twines made of continuous polypropylene and polyamide.

Abrasion resistance—Results of these tests depend very much on the method and mainly on the test machine used and it seems almost impossible to imitate the actual conditions of friction, which affect nets during fishing.

Table III—Abrasion resistance of netting twines, wet (average data)

Polypropylene filament			Polyamide filament		
R tex	Diameter mm	Double frictions	R tex	Diameter mm	Double frictions
211	0·60	35	237	0·55	89
284	0·73	56	307	0·64	84
			489	0·84	141
547	0·99	135			
			708	1·01	364
731	1·19	552			
			785	1·05	628
			917	1·16	722

Twines of exactly the same R tex or the same diameter were not available. Comparisons based on R tex values showed no significant differences between polypropylene and polyamide. This indicates that polypropylene has a very high abrasion resistance, for polyamide is known to be one of the best fibrous materials in this respect.

If twines of equal diameter are compared, the abrasion resistance of polyamide twines is higher than that of polypropylene twines.

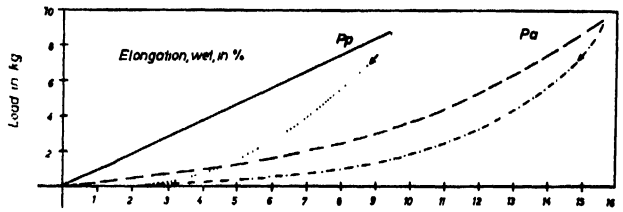


Fig. 4. Load-elongation curves of polypropylene and polyamide netting twines (wet, %). Pp=polypropylene. Pa=polyamide.

Extensibility—The inherent extensibility of synthetic fibres varies, being relatively large for the polyamide group and comparatively small for the polypropylene and polyester groups. The amount of stretching during manufacture is of great influence. The more the fibres are stretched, the more does extensibility decrease and their breaking strength (also per centage losses by knotting), increase. Nearly all polypropylene twines, mentioned in this paper, are of highly stretched material, similar to nylon twines. The form of fibre also influences twine extensibility; staple fibre twines are more extensible

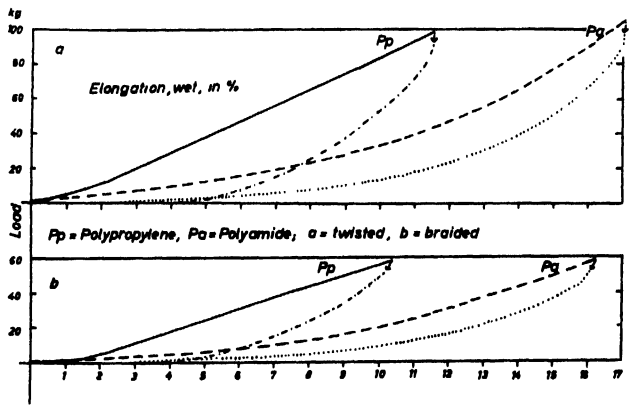


Fig. 5. Load-elongation curves of trawl twines (wet, %). (As in Fig. 4 the curves only reach up to a load corresponding to the knot breaking strength.)

than continuous filament twines. The influence of the amount of twist is shown in Fig. 6 with the nylon twines 2 and 3. It is possible to double extensibility by increasing the coefficient of twist from, e.g., 150 to about 200.

The influence of increasing loads on twine extension is demonstrated by the load-elongation curves of Figs. 4 and 5. Here polypropylene and polyamide twines approximately corresponding in twist and knot breaking strength, are compared. They show remarkably great differences of extensibility—polyamide stretch much more than polypropylene twines—particularly under low loads. (Figs. 4, 5, and 6.)

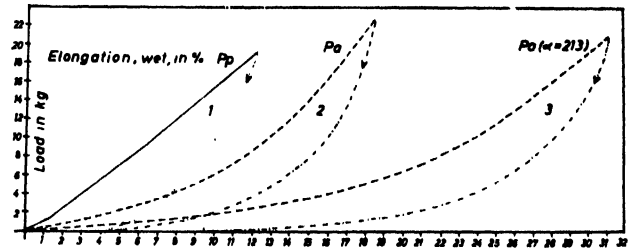


Fig. 6. Load-elongation curves of netting twines (wet, %) made of polypropylene (Pp) and polyamide (Pa). Twines 1 and 2 medium laid (α=150-160), twine 3 hard laid.

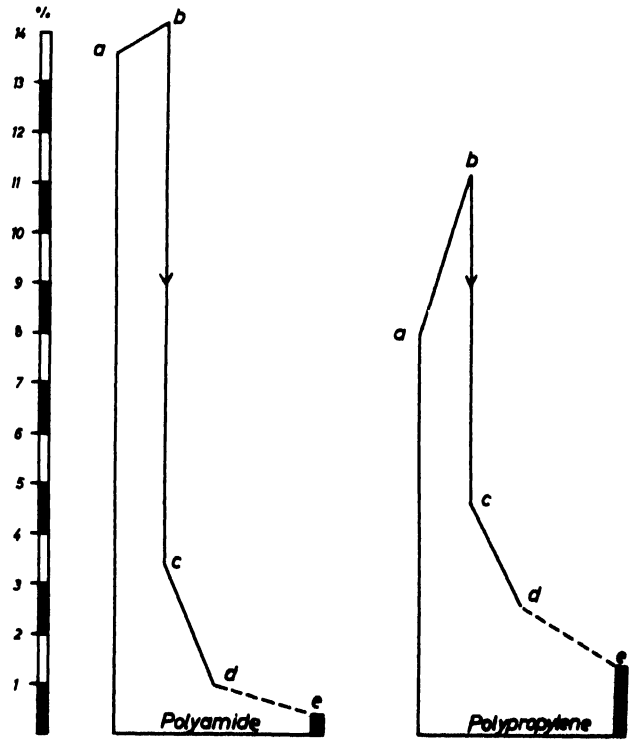


Fig. 7. Elongation and elasticity of wet netting twines loaded for one hour with 30 per cent of their (straight) breaking strength. Elongation: (a)= immediately after loading. (b)=loaded for one hour. (c)=immediately after removal of load. (d)=one hour after removal of load. (e)=permanent elongation.

Elasticity—Because of the factor of duration of time of loading, elasticity was tested by special trials, the results of which are compared in Figs. 7 and 8 and they confirm once more that polyamide twines are more extensible than polypropylene twines—but the permanent elongation of polyamide is lower. A further remarkable difference

between the two kinds of twine becomes evident after longer loading, for instance 24 hours, as in Fig. 8. Polypropylene twines show a "creep" when subjected to loads for prolonged times. Polyamide twines do not change their length during a long period of loading. They show no creep and have a better elasticity.

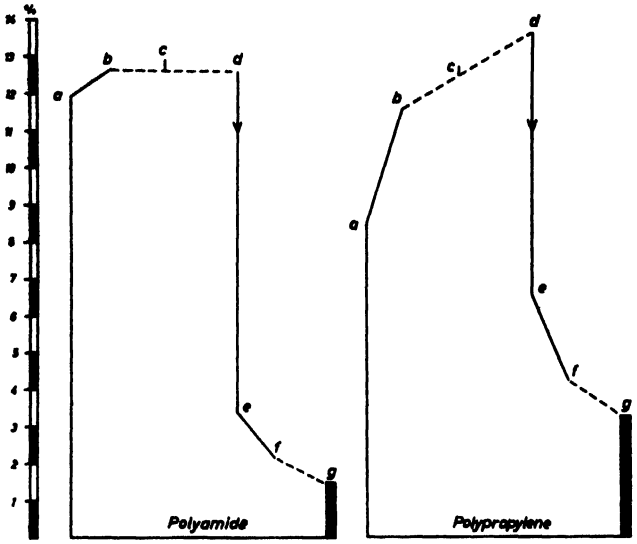


Fig. 8. Elongation and elasticity of dry netting twines loaded for 24 hours with 30 per cent. of their (straight) breaking strength. Elongation: (a) = immediately after loading. (b) = loaded for one hour. (c) = loaded for three hours. (d) = loaded for 24 hours. (e) = immediately after removal of load. (f) = one hour after removal of load. (g) = permanent elongation (measured four days after removal of load).

Experiences and comments

The first trials with polypropylene fishing nets seem to have started in 1961. Experiences, therefore, are still limited.

A report by Carrothers on trials of polypropylene and nylon salmon gillnets in Canada says polypropylene nets were easy to handle and their knot stability was superior to that of nylon nets. In capacity to catch fish, there was no conformity in the experiences of the fishermen. In trials with polypropylene cod gillnets during the Lofoten season carried out by Norwegian fishermen, the polypropylene nets were about 10 per cent lighter and lost less strength during fishing than nylon nets, with about equal catching efficiency.

In a cruise by the USA research vessel *Delaware* an otter trawl, "in which the top wings, top belly and square were constructed of polypropylene fibre twine", was compared with a trawl, entirely made of manila twine. After equal numbers of tows, "The polypropylene-equipped net took 57 per cent fish compared to 43 per cent with the all-manila net". It also gave easier handling, lower water resistance and easier towing.

Trials of British trawlers with trawls entirely made of polypropylene, brought similar results. Especially braided twines were very suitable. These trawls can be towed more easily through the water than comparable manila trawls and give greater headline heights than nylon using the same number of floats.

Midwater trawls

No experiences with polypropylene for this modern gear type are known to the author. Some general remarks can, however, be given.

Fishing gears subject to heavy strain, especially trawls, should on principle be constructed of net material which combines high breaking strength with a twine diameter as small as possible. The small diameter gives less towing resistance. The twines should also have a relatively high extensibility with a high share of elasticity in order to absorb kinetic energy so that the trawl nets can withstand shock loads during fishing and heavy stress when hauling big catches.

For midwater trawls these demands are of particularly great importance. The nets have to be larger and be towed faster than bottom trawls, because pelagic fish are usually fast swimmers. Light and strong nets are, therefore, indispensable. Since twine efficiency depends not only on strength but also on extensibility, midwater trawl twines are relatively high twisted. As shown in Fig. 6, the degree of extension can remarkably be increased in this way. As a high extension obtained by twisting is connected with a considerable decrease in strength, nylon twines should not be manufactured with a coefficient of twist higher than 200. If twine thickness is really of such great importance for the towing resistance, polyamide twines are superior to polypropylene twines (see Fig. 3). Considering extensibility the same fact has to be stated. Because of the low original extension of polypropylene fibres, twines made of these fibres must be twisted to a much higher degree than polyamide twines in order to reach an extensibility suitable for midwater trawls. But with this hard twisting the breaking strength would considerably decrease and the diameter would increase even more.

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Polypropylene Twines in Japan

Abstract
Several Japanese firms started production of polypropylene net twines in 1961. The first products varied in quality, but recently more stable material has been produced and polypropylene twines are now used in the construction of nets in Japan. Although efforts are still in progress to improve the present twines and monofilaments, tests were made to ascertain their properties in relation to other synthetics. Polypropylene has a lower specific gravity (0·91) and a higher breaking strength (g/den) both dry and wet, straight and knotted, than any other fibre material. Water absorption is negligible and consequently there is no loss of strength through wetting. On the basis of equal size (same diameter but lower weight per unit length) it is equal in strength to 'Amilan' but slightly inferior to 'Tetoron' multifilaments. Elasticity and elongation is small at low loads, but breaking energy is 50 per cent greater than that of 'Amilan'. Resistance to weathering and abrasion is still poorer than that of 'Amilan'. No appreciable difference in catchability or ease of handling could be noted during fishing tests when compared with 'Amilan', except that polypropylene was more bulky.

Les fils de polypropylène au Japon

Résumé
Plusieurs entreprises japonaises ont commencé en 1961 à fabriquer des fils de polypropylène pour les filets de pêche. La qualité des premiers produits a beaucoup varié et tout récemment on a mis au point une matière plus stable que l'on utilise déjà pour la structure des filets de pêche. Bien que de gros efforts soient en cours pour améliorer encore les fils et monofilaments actuels, des essais ont déjà été effectués en vue de déterminer les qualités spécifiques de ces fils par rapport aux autres fils synthétiques. Le poids spécifique du polypropylène est inférieur (0·91) et sa résistance à la rupture supérieure (g/den) (que la fibre soit sèche ou mouillée, nouée ou non) à ceux de toute autre fibre. Son absorption d'eau est minime et de ce fait le mouillage n'entraîne aucune diminution de sa force. Sur la base de mêmes dimensions (c'est-à-dire du même diamètre, mais d'un poids inférieur par unité de longueur), la force du polypropylène est égale à celle de 'l'Amilan' mais un peu inférieure à celle des multifilaments de 'Tétoron'. Son élasticité et son élongation aux charges faibles sont restreintes, mais sa résistance à la rupture est de 50 pour cent plus grande que celle de l'"Amilan'. Sa résistance à l'usure du temps ou par frottemen reste inférieure à celle de l'"Amilan'. Pendant les essais de pêche, on n'as pas constaté de différence appréciable entre l'"Amilan' et le polypropylène quant à la capacité de capture et la facilité de l'aménagement du poisson, sauf que le polypropylène se faisait plus volumineux.

Hilos de polipropileno en el Japon

Resumen
Varias empresas Japonesas iniciaron en 1961 la producción de hilos de polipropileno para redes. La calidad de los primeros productos variaba mucho, pero últimamente se ha obtenido un material más estable y estos hilos se emplean actualmente en la construcción de redes. Continúan las investigaciones para mejorar los hilos empleados actualmente, realizándose, además, ensayos para determinar sus propiedades con respecto a otros materiales sintéticos. El polipropileno tiene una gravedad específica más baja (0·91) y una mayor resistencia a la rotura (g/den) tanto húmedo como seco, anudado como sin anudar, que cualquier otro material para fibras. La absorción de agua es insignificante y por lo tanto no hay pérdida de resistencia a causa de la mojadura. A igualdad de dimensiones (el mismo diámetro, pero menos peso por unidad de longitud) es tan fuerte como 'Amilan', pero un poco menos que los multifilamentos de 'Tetoron'. Le elasticidad y el estiramiento son peque nos a cargas reducidas pero la resistencia a la rotura es un 50 por ciento mayor que la de 'Amilan'. La resistencia al desgaste y a la abrasión es todavía menor que la de 'Amilan'. No se observaron diferencias sensibles en cuanto a capturas o facilidad de manipulación en ensayos de pesca en los que se comparó con 'Amilan', aunque el polipropileno resultó ser más voluminoso.

by

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EXPERIMENTAL production of polypropylene was started by several manufacturers in 1961. Of the first products quality was unstable and the resultant fibres unreliable. Products are now more stable and such fibres are beginning to be used in fishing gears.

Investigations towards improvement are still being carried out and the data provided here is not final.

Properties of polypropylene yarns are given in Table I, compared with others productions. From this it can be clearly seen that:

(a) Specific gravity of polypropylene is the lowest among all synthetic fibres. This is a definite advantage for light fishing gear. But it can be a drawback in some gears where sinking speed is important.

(b) Breaking strength, dry and wet, both straight and looped, is greater than that of other synthetic fibres. However, when compared with multifilament yarns of the same size (diameter), polypropylene has the same strength as 'Amilan', but is inferior to 'Tetoron' (polyester). In spun yarns it equals both 'Tetoron' and 'Kuralon' of the same diameter.

(c) As polypropylene absorbs practically no water, its characteristics undergo no changes in wet conditions so that wet strength is as high as dry strength which is an advantage.

(d) The stress-strain curve under loop test is given in Fig. 1. (Mark P.P. as used throughout Figs. 1 to 7 and Table I means polypropylene.) Compared with 'Amilan', polypropylene is difficult to stretch even under low load and its elongation is comparatively small. Its breaking energy is 50 per cent greater than that of 'Amilan'; but if the curves are made for equal diameter (Fig. 2) then the breaking energy is 30 per cent lower. This means that it is weaker than 'Amilan' of the same diameter.

Abrasion tests (Fig. 3) show that polypropylene has a relatively low abrasion resistance and is therefore not well suited for trawls, etc.

Tests for weathering on its strength and elongations (Figs. 4 and 5) made it clear that polypropylene has a much lower resistance to weathering than either 'Amilan' or 'Tetoron'.

As a monofilament polypropylene was found to be superior both in straight and loop tensile strength. For elastic recovery, the results in Fig. 6 show that the elasticity decreases much faster with increasing load than for 'Amilan' of the same diameter.

Impact tests and abrasion tests showed that polypropylene was inferior to 'Amilan' (Table II and Fig. 7).

Polypropylene is more transparent than 'Amilan' but rather stiffer.

Two hundred and fifty polypropylene gillnets made of No. 10·5 (2315d) monofilament twine in 121-mm mesh

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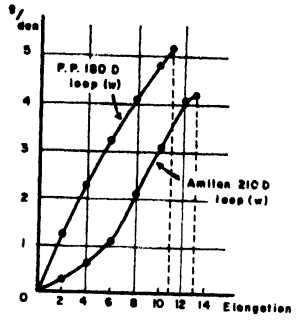

Fig. 1. Stress-strain diagram.

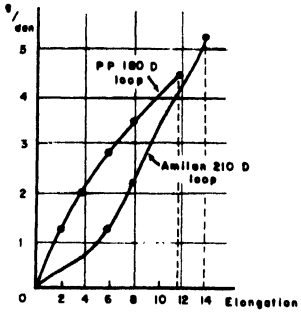

Fig. 2. Stress-strain diagram for equal diameter.

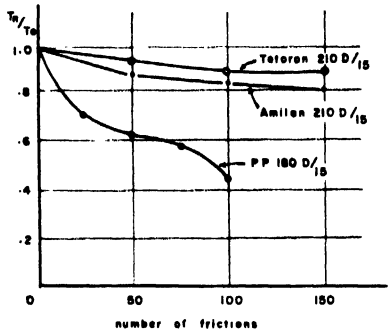

Fig. 3. Abrasive resistance.

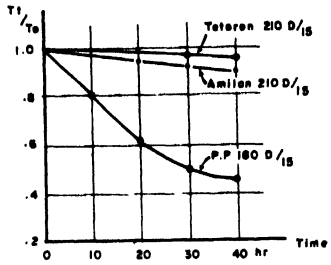

Fig. 4. Loss in strength from exposure.

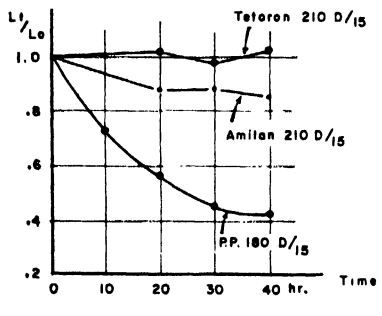

Fig. 5. Elongation decrease from exposure.

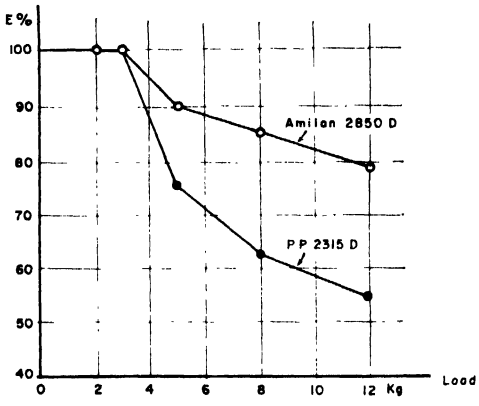

Fig. 6. Monofilament elastic behaviour.

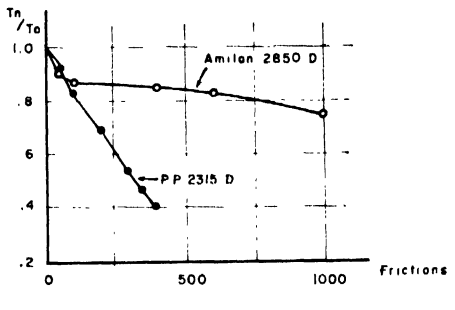

Fig. 7. Monofilament abrasive resistance.

TABLE Ia

Item	Multifilament: P.P. 180 D 20.24 F	Amilan 210 D 15 F	Teteron 210 D 24 F	Saran 360 D 1 F	Teviron 300 D 60 F	Spun: P.P. 20 S	Kuralon 20 S	Spun nylon 22 S	Spun Teteron 20 S
Specific gravity	0.91	1.14	1.38	1.70	1.40	0.91	1.30	1.14	1.38
Breaking strength (g/den) Dry	6.5-7.7	6.20	6.50	2.0	2.50	4.3-4.5	4.50	2.70	2.60
Wet	"	5.20	"	"	2.55	"	4.20	2.40	2.65
Breaking elongation (%) Dry	20.5	18.0	8.0	26.0	20.0	16.0-16.5	10.0	20.0	23.5
Wet	"	19.0	8.5	"	21.0	"	13.0	22.0	24.5
Loop strength (g/den) Dry	4.8-5.3	5.10	4.60	1.3	1.90	3.4-3.6	3.40	2.30	2.25
Wet	"	4.55	"	"	2.00	"	2.80	2.10	2.35
Loop elongation (%) Dry	11.5	11.0	7.0	13.5	12.0	12.5-13.5	7.5	16.5	21.5
Wet	"	13.5	7.5	"	13.0	"	9.5	14.5	23.5
Decreasing of strength by loop Wet	28.0	13.0	29.0	35.0	22.0	20.0	33.0	13.0	11.0
Breaking stress (wet) (kg/mm^2) Straight	53-66	53	81	31	32	35-37	49	24	33
loop	40-43	47	53	20	25	28-30	32	22	29
Absorption (%)	0.1	4.5	0.4	0.1	0.2		5.5		

Item Table Ib	Polypropylene*	Amilan*
Measured denier (d)	2315	2850
Cross section	Ellipse	Ellipse
Breaking strength (kg)	13.2	13.8
Breaking elongation (%)	20.5	33.5
Loop strength (kg)	7.8	8.9
Loop elongation (%)	11.0	16.8
Decrease % of strength, by loop	36.1	35.5
Breaking stress (kg/mm^2) straight	43	49
(in the case of same fineness) loop	28	32

Item Table II	Polypropylene monofilament 2315D, 121 mm	Amilan monofilament 2850D, 121 mm
Impact		
Breaking energy (kg.m) (vertical)	0.51	0.67
Breaking energy (kg.m) (horizontal)	0.61	1.39

Use of 'Ulstron' Polypropylene in Fishing

Abstract
Production of 'Ulstron' for fishing nets will, by the end of 1963, be greater than the total equivalent consumption of all other U.K. synthetic fibres. An oil derivative, polypropylene was invented in 1954 in Milan. Total world production of polypropylene now exceeds 300,000 tons per annum but only a small percentage in the form of fibres, the majority being used as moulding. High-tenacity 'Ulstron' at 8·5 g/den competes with nylon on strength and price basis. Plaited cords may be produced on conventional machinery. 'Ulstron' nets can be constructed on ordinary netting looms such as Zang, Dandy, Amita and Porlester, and are said to offer advantages in both runnage and mesh strength over equivalent nylon. Knot firmness is relatively good but loom tensions in netmaking should aim at 1·0 g/den followed by knot stretching at 1·0 g/den at 100/110°C for 15 minutes while held to fixed dimensions on a stretching frame. 'Ulstron' should not be heated over 110°C. 'Ulstron' yarn may be obtained in and dyed into various colours. Lighter than water, 'Ulstron' is now being used in a variety of fishing gears such as bottom trawls and midwater trawls, gillnets, Danish seines and purse seines, etc., as well as in ropes, where it is in the same strength bracket as nylon and polyester ropes, but has a considerably greater runnage and is cheaper per unit length of equal strength.

by
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L'Utilisation du polypropylène 'Ulstron' dans l'industrie de la pêche

Résumé
La production d'"Ulstron' pour les filets de pêche sera, à la fin de 1963, supérieure à la consommation totale de toutes les autres fibres synthétiques pour le Royaume-Uni. Le polypropylène, dérivé d'une huile minérale, a été inventé à Milan en 1954. La production mondiale totale de polypropylène excède maintenant 300,000 tonnes par an, mais un faible pourcentage seulement sert à la fabrication des filets, la majorité étant utilisée pour les plastiques. L'"Ulstron' de haute ténacité à 8,5 g/den peut rivaliser avec le nylon au point de vue résistance et prix. Des cordes tressées peuvent être produites sur les machines traditionnelles et les filets d'"Ulstron' peuvent être fabriqués sur des métiers ordinaires comme Zang, Dandy, Amita et Porlester. Ils sont sensés offrir des avantages sur les filets en nylon de denier équivalent, en ce qui concerne le rapport m/kg et la résistance des mailles. La stabilité des noeuds est relativement bonne mais la tension sur le métier pendant la fabrication devra être dirigée vers 1 g/den, suivie d'un étirage des noeuds à un g/den, 100/110°C pendant 15 minutes, en tenant le filet fixé sur un cadre. L'"Ulstron' ne doit pas être chauffé audessus de 110°C. Le fil de filet 'Ulstron' peut être obtenu dans diverses teintes. Il flotte sur l'eau et est maintenant utilisé pour des engins de pêche variés tels que: chaluts de fond, chaluts pélagiques, filets maillants, sennes danoises, sennes coulissantes, etc., aussi bien que pour des cordes où l'"Ulstron' est l'égal du nylon et du polyester en ce qui concerne la résistance à la rupture, mais est beaucoup plus long au kilo et est beaucoup moins cher par unité de longueur pour la même resistance.

El empleo de polipropileno 'Ulstron' en la industria pesquera

Extracto
La producción de 'Ulstron' para redes de pesca será, para fines de 1963, mayor que la de todas las demás fibras sintéticas en el Reino Unido. El propileno es un derivado del petróleo descubierto en Milán en 1954. La producción mundial total de la sustancia excede de 300.000 tons anuales, pero sólo una pequeña proporción en la forma de fibra y la mayor parte para moldes. El 'Ulstron' de gran tenacidad a 8,5 g/den compite con el nylon en robustez y precio. Las cuerdas trenzadas pueden fabricarse en las máquinas normales. Las redes de 'Ulstron' se manufacturan en los telares corrientes como el Zang, Dandy, Amita y Porlester y se dice que resultan ventajosas en cuanto al peso por longitud y resistencia de la malla con respecto al nylon equivalente. El nudo es bastante firme, pero las tensiones en el telar, cuando se hacen redes, deberían ser del orden de 1,0 g/den, seguidas de estiramiento del nudo a 1,0 g/den a 100-110°C durante 15 min mientras se sujeta a dimensiones fijas en un armazón de estiramiento. El 'Ulstron' no deberá calentarse a más de 110°C. Sus hilos pueden prepararse de cualquier

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size nets were tested in the North Pacific Ocean from May to July, 1962, for salmon and trout. The catch ratio per net appeared to average approximately that of 'Amilan' nets of the same diameter and were as follows:

Polypropylene	1·30-1·45
'Amilan' nets made in 1961	1·00
'Amilan' nets made in 1962	1·50-1·65.

The polypropylene nets were found to be two to three times more voluminous than 'Amilan' ones and tended to blow about easily, making them liable to fouling during hauling and shooting.

As regards fishing damage it would appear that the number of tears is twice that of the 'Amilan' nets but the knot slippage was very much lower.

After the trials, the nets were again tested and it appeared that the strength had increased during use so that it was now higher than that of 'Amilan'. No change in mesh size as a result of the trials could be ascertained.

Polypropylene nets made of multifilament 180d/15 were made in 121-mm mesh size and operated together with 'Amilan' and 'Tetoron' nets made of equal diameter twines.

Catches per net were as good as those of contemporary 'Amilan' nets and normally better than older nets.

In handling they were more bulky and tended to blow about.

About 600 nets made of polypropylene staple yarn 20s/15 (resin treated, singed) were operated from April to August 1962, for a period of 103 days, together with nets made of 'Kuralon'.

The experiment showed that catches were higher than those of the 'Kuralon' nets and, while the handling of the nets was fairly good, there was more difficulty in retrieving the crabs than with the 'Kuralon' nets.

The nets were tested after use and it was noticeable that, whereas the monofilament and multifilament nets slightly increased in breaking strength and decreased in extensibility, the opposite occurred with these staple yarn nets.

color o teñirse de igual manera. Es menos denso que el agua y se emplea actualmente en la fabricación de artes de arrastre y flotantes, redes de enmalle, artes daneses y redes de cerco de jareta, así como en cabos de todas clases en los que tiene la misma robustez que los de nylon y poliesteres, pero entran muchos más metros en kg y es más barato por unidad de longitud de la misma resistencia.

'ULSTRON' polypropylene is rapidly becoming the leading synthetic fibre for the production of fish netting in the U.K. It is already used for a wider range of fish nets than any of the other synthetics, and production of 'Ulstron' for nets and other fishing applications will, by the end of 1963, be greater than the total equivalent consumption of all the other U.K. synthetic fibres.

Polypropylene is the latest synthetic fibre to be developed for the fishing industry and this paper outlines the properties of 'Ulstron', I.C.I.'s brand of polypropylene, and describes the experience to date in net production and use.

Discovery and development

Polypropylene has been known for many years as an oil, although, for various reasons, it had no commercial importance. In 1954, at the Polytechnic Institute of Milan, Professor Natta, whose work had been concerned with the stereospecific polymerisation of olefines using organometallic catalysts of the Zeigler type, discovered how to make isotactic material with a regular ordered molecular structure. This raised the melting point for 20 to 40°C to 165°C and altered the whole future of polypropylene as both a plastic and fibre material. Propylene is derived from oil, being a gas which is obtained at the same time as ethylene by cracking petroleum. As a point of interest, 'Terylene' and polythene are also derived from oil while nylon is derived from coal.

I.C.I. recognised the great potential for this new material and negotiated a patent licence from the Italian chemical firm of Montecatini in August, 1960. This agreement covered the exclusive production and sale in the U.K. by I.C.I. of polypropylene filament yarn, staple fibre and textile monofilaments. To the high tenacity multifilament and monofilament polypropylene yarns, I.C.I. has given the trade name 'Ulstron'. A large plant, with an eventual capacity of 5,000,000 lb per annum, is now in production and work is proceeding to extend this capacity still further.

Total world production of polypropylene is now estimated to exceed 300,000 tons per annum but at present only a small percentage is in the form of fibres, the majority being supplied for plastic uses such as moulding. With most brands of polypropylene fibre the tenacity (6 g/den) has been considerably below that of nylon (7½-9 g/den) and this has undoubtedly held back a more rapid expansion in the fishing industry than would otherwise have been expected from its outstanding properties of lightness and low price. 'Ulstron' at 8·5 g/den is the first (and, at present, only) brand of polypropylene to be fully competitive with nylon on strength as well as price. This accounts for its rapid progress at the expense of nylon and other synthetics which it is replacing, a pattern which is likely to occur in other parts of the world during the next few years as other brands of polypropylene become more fully developed.

Some details of this new material will therefore be of particular interest.

Properties of 'Ulstron'

'Ulstron' has a low density, high wet strength and extremely high capacity for withstanding shock loads. Its properties are compared with those of other yarns used in fish net manufacture in Table I. Other advantages include a good resistance to chemical and micro-biological attack (Table II) and negligible water absorption. It is currently produced in the following deniers:

190 den (Decitex 211), 380 (Decitex 422), 570 (Decitex 633), 760 (Decitex 844), 1,140 (Decitex 1,270), in both natural and melt coloured green.

Twine making

'Ulstron' twines and nets are constructed in much the same way as other synthetic materials but, because of their lower liveliness compared with nylon or 'Terylene'

TABLE I—Comparative filament yarn properties

Property	'Ulstron'	Polyethylene	'Terylene'	Nylon	Polyvinyl Alcohol	Cotton*	Manila*	Sisal*
Tenacity (g/den)	8·0–8·5	4·5–6·0	6·0–7·0	7·0–9·0	3·0–7·0	1·5–2·0	2·3–2·9	2·4
Extension at Break (%) ..	18–22	25–35	6–14	12–18	15–28	3–10	2–3	2–2·5
Elastic Recovery (% from 5% Extension)	88	88	90	98	60–75 at 3% Ext.	45	Breaks	Breaks
Working Load Extension ..	1·11	2·22	·91–·77	1·5–1·3	0·91	8·4–1·4	6·75	6·75
Initial Modulus (g/den) ..	90	45	110–130	45–55	110	12–70	148	148
Toughness × 10^3 (joules/g) ..	80–100	85–90	28–50	55–89		3·4–8·5	4·0	3·0
Wet Tenacity (g/den).. ..	8·0–8·5	4·5–6·0	6–7	6·0–7·9	2·6–5·9	1·8–2·4	2·3–2·9	2·2
Wet Extension (%)	18–22	25–35	6–14	19–28	20–30	2·5–8·0	2·5–3·5	2–3
Moisture Regain (%).. ..	0·1	0·15	0·4	4·2	5	8	13	13
Softening Point	160–170	110–140	260	250	215–225	—	—	—
Specific Gravity of Fibre ..	0·91	0·95	1·38	1·14	1·26–1·3	1·54	1·48	1·49

* The tensile properties quoted for cotton, manila, sisal of necessity refer to spun yarns, which have an overall tenacity lower than that of the individual single fibres.

TABLE II—Chemical resistance data

Chemical	Conc. W/W (%)	Temp. (°C)	Time (hour)	Residual Strength (%) Nylon	Polyester	'Ulstron'
Acids:						
Hydrochloric	34	20	100	0	89	100
Nitric	66	20	100	0	71	100
Sulphuric	96	20	100	0	0	100
Sulphuric	96	70	20	0	0	95
Sulphuric	50	70	150	0	83	90
Formic	90	20	100	0	100	100
Acetic	100	20	10	86	92	100
Alkalis:						
Caustic Soda	40	20	100	90	0	90
Caustic Soda	20	70	150	100	0	100
Caustic Potash	40	20	100	90	0	90
Solvents:						
Trichlorethylene	100	30	150	N.A.	N.A.	75
Trichlorethylene	100	at the boil	8	N.A.	N.A.	70
Carbon Tetrachloride	100	20	150	100	100	100
Benzene	100	70	150	100	100	100
Benzene	100	at the boil	4	85	92	95
Metacresol	100	70	150	0	0	100
Metacresol	100	100	4	0	0	100
Oxidising Agents:						
Sodium Hypochlorite	5% active Cl_2	20	100	N.A.	95	85
Hydrogen Peroxide	12 volume	20	100	N.A.	100	90

N.A. = No data available

twines, twist setting is less important. In twisting 'Ulstron' twines, it may be found necessary to employ ring travellers one or two sizes lower than are used for nylon twines of equivalent numbers of plies, owing to the lower density of the material.

'Ulstron' twines, matching in twist-hardness nylon twines of 210-den yarns, will be obtained by using one 190-den yarn for each 210-den yarn and employing twist levels at all stages which are some five per cent lower than for the nylon twine. Where high extensibility and high bending stiffness are required hard twines will be constructed; where the net is to be subsequently bonded, soft twines will be adequate. Twist levels which have been employed in constructing hard and soft 'Ulstron' twines based on 190-den yarn are given in Fig. 1.

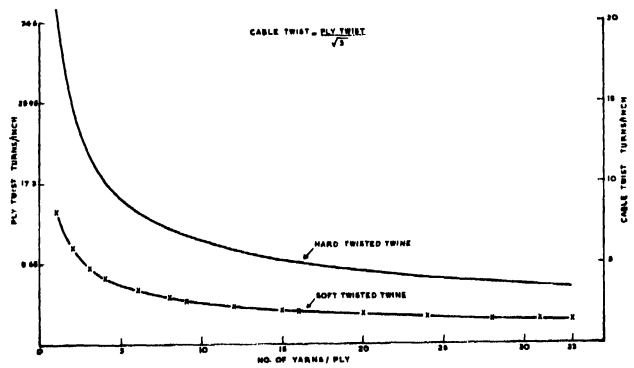

Fig. 1. Ply twist for three-ply twines based on 190-denier 'Ulstron' yarn

Equivalent twist hardnesses for 'Ulstron' twines, based on the same number of plies of any other denier, may be calculated from the formula

$$T_2 = T_1\sqrt{\frac{190}{d}}$$

where d is the yarn denier to be used, T_1 the twist (tpi) for twines based on 190-den 'Ulstron' and T_2 the twist to be used in the twine to be constructed. Balanced twines are produced exactly as for other materials by making:

$$\text{cable twist (tpi)} = \frac{\text{ply twist (tpi)}}{\sqrt{\text{no. of plies}}}$$

although, because any unbalance in 'Ulstron' twines tends to decay, there is more latitude for error than in producing balanced 'Terylene' or nylon twines.

Plaited or braided cords may be produced on conventional machinery into either hard extensible braids or soft inextensible braids. Ends/spindle, spindles/braid and picks per inch can be almost identical for 'Ulstron' braids based on 190-den yarn to those employed for 210-den nylon braids with equivalent numbers of ends.

Comparative properties

All the advantages which 'Ulstron' yarn offers over competitive yarns are retained when twine properties are compared. 'Ulstron' yarns are produced in multiples of 190 den and so, when compared with 210-den nylon twines of equivalent number of plies, they have approximately 10 per cent runnage advantage. Table III shows that 'Ulstron' twines have, in addition, a small wet strength advantage over their nylon equivalents.

TABLE III—Comparative wet knot strength of 'Ulstron' and nylon twines

No. of Plies 190-denier 'Ulstron' 210-denier Nylon 6,6	Nylon Wet Knot Bld (lb)	% Ext	'Ulstron' Wet Knot Bld (lb)	% Ext
27	42·6	24·0	51·0	13·0
36	49·1	22·0	55·0	13·0
42	62·6	26·0	68·7	14·2
60	78·4	21·0	85·6	15·0

N.B. (1) Runnage advantage to 'Ulstron' $= \frac{210-190}{210} + 9\frac{1}{2}\%$

(2) Twines constructed at comparable twist hardnesses.

Similar comparisons and conclusions can be made about the strength and weight advantages of 'Ulstron' in netting form. It can be seen from Table IV below that 'Ulstron' nets offer an advantage in both runnage and mesh strength over equivalent nylon nets over a wide range of mesh sizes and constructions. Nylon is used for a basis of comparison because of its former pre-eminence in the industry.

TABLE IV—Physical properties of gillnets

Net Construction (1)		Runnage (2)		Wet mesh strength (lb)	
Ply	Mesh size (in)	'Ulstron'	Nylon	'Ulstron'	Nylon
2	2·5	165·5	154	6·1	5·0
2	2·6	172	156	6·1	5·2
2	3·1	184	160	6·1	5·8
2	4·5	433	411	6·2	5·3
3	4·5	292	268	9·3	7·9
9	6	84·4	75·5	27·4	23·0
15	5·5	44	39	45·8	42·8
18	4·1	26	23	53·3	54·4

(1) Number of plies of 190-denier 'Ulstron' or 210-denier nylon.
(2) The runnage is expressed as the number of square yards of net per lb, the meshes being fully open and squarely aligned.

Net making and finishing

'Ulstron' nets may be constructed on any of the netting looms in common use such as the Zang, Dandy, Amita or Porlester. Table V and Fig. 2 show that such nets show very little knot inversion in fishing and less tendency for knot opening in transportation from loom to stretching frame than equivalent 'Terylene' and nylon nets subjected to identical stretching and stabilising treatments. Knot slippage may nevertheless occur unless adequate precautions are taken.

TABLE V—Load in kg to invert double knots tied under a tension of 625 gms

Nylon 6 × 210	1·73
Early 'Ulstron' 6 × 190	1·85
Current 'Ulstron' 6 × 190	2·30
Current 'Ulstron' 6 × 190, relaxed in boiling water for 15 minutes	2·7
Current 'Ulstron' 6 × 190, stretched under a load of 1 gpd at 110°C for 5 minutes	3·1

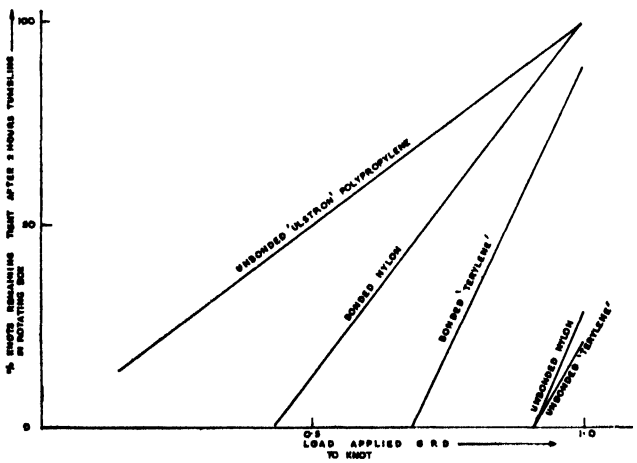

Fig. 2. Relation between slippage and knotting tension.

Loom tensions in netmaking should be as high as is consistent with smooth running, and maximum levels of 1·0 g/den should be aimed for. Subsequent stretching should be at a tension of at least 1·0 g/den if carried out cold, but preferably the net should be subjected to a temperature of 100/110°C for 15 min whilst held to fixed dimensions on a stretching frame. 'Ulstron' nets should never be subjected to temperatures exceeding 110°C. If these precautions are followed, the knot stability will be found satisfactory without using twine or net bonding agents. Good knot stability can also be obtained by heat relaxing the net at 100/110°C for 15 min after stretching, but only at the expense of some 8 to 10 per cent shrinkage compared with six to eight per cent for nylon. Satisfactorily stable knots are obtained in 'Ulstron' nets made from braided cords even when no heat treatment is used and at deniers in excess of 20,000 there is no need to stretch the nets.

Where facilities for heat treatment of 'Ulstron' nets made from fine twines are not available, it is necessary either to employ considerably higher net stretching tensions than usual or to apply a suitable knot bonding agent. Such agents may also be applied where the fishermen require a high degree of stiffness, as for wing trawls.

A number of bonding agents have been examined for their effect on knot inversion. Not all the agents examined produced an improvement. In general, bonding of knots produced an improved stability whilst bonding of the twine gave a lowered stability. Among those agents which produce a noticeable increase in stability are 'Bitumen PE4', 'Vinamul' N6515, N6530, 'Cuprinol' and 'Marstein'. In most cases, the solution should be diluted to ensure the correct pick-up which will vary with the dilution, the size of twine in the netting, and whether the net is mechanically dried or not but should be as low as possible compatible with the required improvement in knot stability and stiffening of the twine. The 'Bitumen PE4' treatment which is often used for bottom trawls, besides stiffening the twine, protects it from the abrasive wear of the sea bed and reduces the uptake of sand and mud.

'Ulstron' yarn may be obtained in natural colour, melt dyed green, or in special cases melt dyed black. If other colours are required, the nets can be dyed with one of the following range of disperse dyestuffs:

'Supracet' Yellow 2G	'Cibacet' Blue GF
'Resolin' Yellow 5R	'Dispersol' Yellow PP
'Serisol' Fast Pink RGL	'Dispersol' Red PP
'Foron' Brilliant Violet BL	'Duranol' Blue PP.

All these give adequate depth of shade and rub fastness. These dyestuffs are applied at 85 to 100°C and full depth of shade may be obtained in some 30 min. Unless the net can be held to length in dyeing, a net shrinkage of up to nine per cent must be allowed for.

Mounting requirements

'Ulstron' nets are themselves lighter than water and therefore need adequate weighting. The mounting requirements vary according to the type of net used:

in mounting gillnets which have already a weighted sinkerline, it is merely necessary to increase the weighting to compensate for the lower weight of 'Ulstron'. When netting which weighs 1 lb in air is immersed in water, the actual weight in water is $\frac{D-1}{D}$ where D is the specific gravity of the fibre. Hence the weight of 1 lb (air weight) of various nets immersed in water for long enough to displace all entrapped air is:

1 lb (air weight) of cotton netting	—0·33 lb negative buoyancy
1 lb (air weight) of nylon netting	—0·12 lb negative buoyancy
1 lb (air weight) of 'Ulstron' netting	—0·10 lb positive buoyancy.

Thus in changing from cotton to 'Ulstron' netting an extra 0·43 lb of weighting should be added (if necessary) to the sinkerline for every 1 lb (air weight) of cotton netting previously used.

In mounting trawlnets the aim is often to secure maximum headline/footrope separation, which depends principally on the design of the net. In changing to 'Ulstron' from the denser fibres, therefore, no great increase in headline/footrope separation should be expected but instead it should be possible to reduce the number of floats without impairing the shape of the net in fishing. The use of fewer floats will reduce the drag of the net, which may lead to valuable savings in power.

Fishing performance—bottom trawls

The most important property of a bottom trawl is its fishing efficiency, which depends upon many factors, some of which favour the use of 'Ulstron'. Among the favourable factors is the lower drag which can be obtained by reducing the number of floats on the headline whilst keeping the same trawl mouth opening. One unfavourable factor is the smooth surface and small knot size of 'Ulstron' multifilament trawl meshes, which may permit more of the smaller fish to escape, but this applies equally to other synthetic fibres.

Since catches are highly dependent upon the efficiency of the skipper, the season, the weather, and the state of the sea bed, it is difficult to make a meaningful comparison of fishing power. All that could be said after a trial, in which four trawling companies fished 'Ulstron' trawls for a total of 12 trips, was that there was no significant difference between their catching power and of the manila trawls previously used. Thus although the 'Ulstron' trawls caught an average of 82·1 kits/net/day against 69·7 kits/net/day for equivalent-sized boats fishing the same grounds over the same periods, most of the difference could be explained by the superior fishing ability of the boats used in the trial; before the 'Ulstron' nets were supplied, the boats concerned in the trial caught on average 12 per cent more fish/net/day than the mean for all the boats fishing at the same periods.

Although no clear-cut answer emerges on fishing

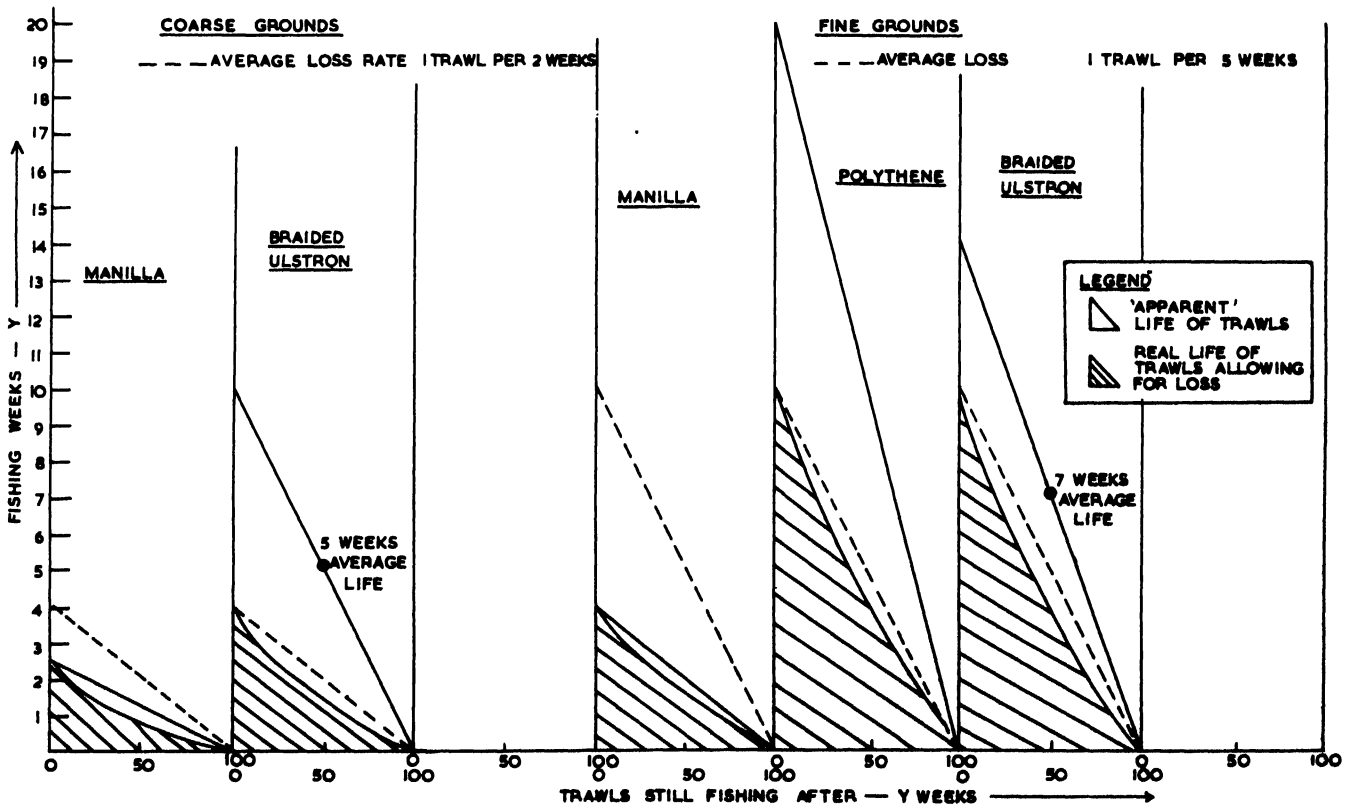

Fig. 3. Price/life relationship from trials on fishing efficiency.

efficiency from the trials, the price/life relationship is very much clearer (Fig. 3). In coarse ground fishing the average life of braided 'Ulstron' trawls (if not lost) is some five weeks' fishing. Making allowances for accidental losses by snagging on submerged objects and similar mishaps, the average life is reduced to some two to three weeks. The corresponding average life for manila trawls, again taking accidental loss into account, is some 1 to 1½ weeks, or rather less than one full trip. Since 'Ulstron' Granton trawls in braided multifilament cost in the region of £160 to £210 compared with some £130 for manila trawls based on equivalent diameter cords, the 'Ulstron' trawls have an advantage of about 50 per cent over manila trawls on a price/life basis. Similar considerations apply in fine ground fishing where the rates of accidental loss and severe damage are much lower. Fig. 3 shows that trawls in more costly materials than 'Ulstron' would be uncompetitive in the market, even if they had a higher resistance to normal sea-bed abrasion, simply because of the chance of complete loss.

Measurements have shown that 'Ulstron' trawls constructed from braided cords show no mesh-size changes greater than three per cent in practical fishing up to three trips. 'Ulstron' trawls braided from twisted twines show a small initial mesh-size increase associated with knot tightening. After fishing for three trips, the meshes decrease in size owing to penetration of sand and other particles into the cords; but this shrinkage is less with 'Ulstron' than it is with other trawl materials which absorb moisture and so suffer from direct yarn shrinkage as well as sand penetration. Accordingly, it is possible to braid 'Ulstron' trawls to their desired final mesh size more accurately than for other materials. Closely associated with the relative constancy of mesh size in an 'Ulstron' trawl, and stemming from its knot stability and its low moisture uptake, is the fact that the International Meshsize Regulations governing minimum mesh size are less likely to be infringed by 'Ulstron' trawls which are very light. A full bottom trawl weighs about 250 lb compared with 450 lb for the equivalent net in manila. They are easy to handle and because of their low moisture uptake behave well in freezing conditions.

Eighty per cent of Norway's large trawlers now use 'Ulstron' nets and they are being increasingly adopted by nearly all the U.K. trawler companies. The Silver Cod Trophy, awarded annually by the British Trawlers Federation to the skipper landing the greatest volume of fish, was won in 1962 by *Somerset Maugham* which was largely using 'Ulstron' netting.

Midwater trawls

Midwater trawls are generally treated with a stiffening agent to ensure that the nets retain their hydrodynamic shape. The benefit of using a netting material sufficiently light to permit a reduction in floats is greater with midwater trawls than for bottom trawls and the American report on the cruise of the U.S.S. *Delaware* suggests that fuel bills for towing 'Ulstron' midwater trawls may be somewhat less than for heavier materials.

Results so far available show a wide variation in reported catching power between boats, with some skippers unenthusiastic whilst their neighbours are reporting much higher catches. Undoubtedly much depends upon intelligent mounting of the new material and upon the use of an adequately rigid bonding agent. Nevertheless, all the reports welcome the lightness and ease of handling 'Ulstron' midwater trawls.

Gillnets

As in trawlnets, fish-catching power is of critical importance. In this case the relative fish-catching power of nets in two materials is somewhat easier to measure since the nets to be compared can be fished at the same time and under the same conditions. The comparisons have been chiefly with nylon, since the superiority of this fibre in fish-catching power over other netting materials such as cotton was already well established before 'Ulstron' was introduced.

Fig. 4 shows measurements of the fish-catching power of a range of different types of 'Ulstron' and nylon nets. In some cases the differences can be simply explained. Thus, the salmon leader nets did not incorporate weights on the "non-return valves" leading to the net bags so that on the ebb tide the 'Ulstron' valves, formed of netting panels, closed too rapidly and prevented the entry of fish.

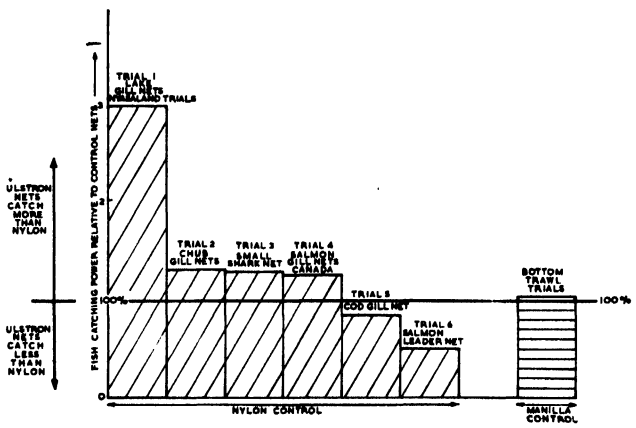

Fig. 4. Fish-catching power of 'Ulstron' nets.

The other differences are less easy to explain. It was emphasised in the section on mounting that where an 'Ulstron' net is set on to a shorter support rope it will bag upwards, whereas a nylon net would bag downwards. In these circumstances the 'Ulstron' net would catch more of the fish swimming near the surface and this may explain the superiority of the 'Ulstron' salmon gillnets. A further reason for genuine differences in catching power stems from the difference in extensibility of the two materials. 'Ulstron' meshes are less extensible at low loads than are nylon meshes so that they will release fewer fish whose girth is only slightly greater than the mesh size. Conversely, fewer fish of girth appreciably greater than the mesh size will be able to penetrate the 'Ulstron' meshes

than could become entrapped in a nylon mesh. To some extent, therefore, the relative fish-catching power of 'Ulstron'and nylon nets will depend upon the size of the fish being caught in relation to the mesh size. The difference in extensibility may be the explanation of two features reported by a number of fishermen: namely, the ease of removing the fish by hand from the net and the reduced damage to fish compared with nylon.

The most extensively documented trial so far carried out on 'Ulstron' gillnets was a trial with cod gillnets in the Lofoten Islands. (Fig.4). The result on fish-catching power showed that in this particular trial, in which six boats fished a total of 30 nets for 42 days, there was no statistically significant difference in fish-catching power between the 'Ulstron' and nylon nets. The trial was interesting in that it showed that the average loss in strength of the nets after one year's fishing was 16 per cent for the 'Ulstron' nets and 24 per cent for the nylon controls. These results are again so close as to be statistically inseparable but they serve to show that the strength losses in fishing from all causes are no greater than those found with nylon netting.

Some outstanding results were reported from Nyasaland where a single 'Ulstron' net caught nearly as much as 14 nylon nets of similar construction being fished alongside. Catches during three fishing periods were:

Single 'Ulstron' net	14 Nylon nets
20 dozen	52½ dozen
25½ dozen	50 dozen
104½ dozen	82 dozen
150 dozen	184½ dozen = 13 dozen per single nylon net

In another trial, supervised by one of the East African Fisheries Officers, similar 'Ulstron' and nylon nets were fished for 36 days on small shark. During this period 'Ulstron' caught 416 lb and nylon 319 lb. At the end of this period, however, the nylon nets were no longer serviceable whereas the 'Ulstron' was still considered to have half its life remaining.

It is well known that wide variations can occur in fishing results but it has been reasonable to deduce from these and other trials that the performance of 'Ulstron' is at least as good or better than that of nylon and contrary to some expectations the slightly greater diameter of an 'Ulstron' gillnet twine, compared with equivalent ply nylon, does not have any detrimental effect on catching power.

Other nets

'Ulstron' has been found very satisfactory for the production of Danish Seine nets and a large number of seiners, particularly from Grimsby, have now changed to it. Twisted twine has generally been used in runnages from 460 m/kg to 180 m/kg although there has been some usage of braided twine, particularly for the codend.

'Ulstron' has made some progress in the wing trawl market against considerable competition from polythene monofil, which has been established for some time. The greater strength, lower price and ease of mending of 'Ulstron' are, however, finding favour with many fishermen.

An interesting recent development has been the use of 'Ulstron' in ringnets, a small type of purse seine used largely in Scotland for herring. In some instances only part of the net has been made from 'Ulstron', the balance being in cotton or nylon. A number of 100 per cent 'Ulstron' ringnets have, however, been produced and fished successfully. In spite of the buoyancy of 'Ulstron' no difficulty has been reported in getting the nets to sink properly and it is therefore likely that, with proper rigging and weighting, it will be possible to produce purse seines in 'Ulstron' where the reduction in weight will give lower prices and easier handling.

Other uses for 'Ulstron' include trap netting, lobster pots, anglers' keep netting, lines, snoods and dyed mending twine. Trial quantities of knitted, knotless netting have also been produced. Further trials are in progress evaluating 'Ulstron' monofilament yarn and twines in various types of net.

Ropes

The second largest use for 'Ulstron' is in the production of ropes, many of which are used for fishing purposes particularly in Norway.

'Ulstron' rope is in the same strength bracket as nylon and polyester rope and considerably stronger than polythene rope but has considerably greater runnage than nylon and polyester as shown below (for 1 in circ):

	lb per 120 fm	B/load (lb)	Cost per 100 ft*	pence/ton/foot
'Ulstron' ..	16·0	2,100 lb	37s. 6d.	4·80
Nylon ..	21·5	2,240 lb	48s. 9d.	5·85
'Terylene' ..	24·75	2,100 lb	58s. 8d.	7·50

* Typical U.K. price

The 'Ulstron' rope has been largely used as mounting ropes for cod, herring and other types of gillnets; in some cases the netting itself has been 'Ulstron' but in many cases 'Ulstron' rope has been used with nylon or other types of netting. The reports on the ropes have been very satisfactory.

One particularly interesting development in the rope field has been the introduction of ropes made partly or wholly from 40-in length 5,000 diameter polypropylene staple fibre. This long staple 'Ulstron' has been specially developed by I.C.I. and a leading U.K. ropemaker. It is processed on standard hard fibre machinery into either 100 per cent spun 'Ulstron' rope, which is as strong as 'Ulstron' multifil rope, or into 35/65 or 50/50 polypropylene/sisal blended ropes which are cheaper but not quite so strong and to which the trade name 'Systron' has been given. These ropes are cheaper than other synthetic ropes and have performed well in trials as trawl quarter ropes and for other uses.

Twines can only be produced from this new staple fibre at runnages less than 900 yds/lb, so its use in the fishing industry is restricted to ropes and heavy trawl twines.

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Synthetic Fibre Fishing Nets and Ropes Made in Japan

by
Japan Chemical Fibres Association

Abstract

The estimated production of synthetic fibre for fishing nets and ropes in Japan is estimated at 45,000,000 lb in 1962, of which about 32,000,000 lb was used for making fishing nets, the latter having increased from 21,000,000 lb in 1959. On the other hand, the production of natural fibre fishing nets (cotton, hemp, etc.) declined from some 28,000,000 lb in 1949 (when synthetic fibre net manufacture started) to only about 3,000,000 lb in 1962. About 85 per cent of Japanese fishing nets are now made of synthetic fibres. Initially nylon, vinylon, polyvinylidene chloride and polyvinyl chloride fibres were mainly used but after 1959 polyethylene and polyester were added, and polypropylene in 1962. Exports of synthetic fibre fishing nets have increased from 400,000 lb in 1955 to about 70,000,000 lb in 1961, shipped to more than 100 nations. In 1961 nylon and vinylon each accounted for 41 per cent of synthetic fibre nets, polyethylene six per cent, polyvinylidene five per cent, polyvinyl chloride two per cent, polyester one per cent and blended fibres four per cent. In lines and ropes vinylon accounts for 53 per cent and polyethylene for 23 per cent. Almost the entire output of ropes of blended fibres is exported.

Filets et cordes fabriques en fibres synthétiques

Résumé

Au Japon, la production de filets et cordes en fibres synthétiques est estimée pour 1962, à 20.000 tonnes, dont 15.000 pour la fabrication de filets, celle-ci ayant augmenté de 9.500 tonnes depuis 1959. D'autre part, la production de filets en fibres naturelles (coton, chanvre, etc.) a diminué de 13.000 tonnes en 1949 (début de las fabrication des filets en fibres synthétiques) à 1.330 tonnes en 1962. Aujourd'hui environ 85 pour cent des filets japonais sont faits en fibres synthétiques. Initialement, les fibres de nylon, vinylon, polyvinylidène chloride et polyvinyl chloride étaient surtout utilisées mais, depuis 1959 on a introduit le polyéthylène et le polyester puis, en 1962, le polypropylène. Les exportations de filets en fibres synthétiques vers plus de 100 pays, sont passées de 180 tonnes en 1955 à 32.000 tonnes en 1961. En 1961, 41 pour cent des filets en fibres synthétiques étaient fabriqués en nylon et vinylon, six pour cent en polyéthylène, cinq pour cent en polyvinylidène deux pour cent en polyvinyl chloride, un pour cent en polyester et quatre pour cent en fibres mixtes. Quant aux filins et cordes, 53 pour cent étaient faits de vinylon et 23 pour cent de polyéthylène. Presque toutes les cordes en fibres mixtes sont exportées.

Redes y cabos de pesca de fibras sinteticas fabricados en Japon

Extracto

La producción japonesa de fibras sintéticas para cabos y redes de pesca se estima en 45 millones de libras en 1962, de las que 32 millones de emplearon para fabricar redes. En 1959 se emplearon con el mismo objeto 21 millones de libras. Por otro lado, la producción de redes de pesca de fibras naturales (algodón, cáñamo, etc.) disminuyó de unos 28 millones de libras en 1949 (año en que comenzó la fabricación de fibras sintéticas), a unos tres millones de libras en 1962. Actualmente, el 85 por ciento de las redes de pesca japonesas se hacen de fibras sintéticas. Inicialmente, las que más se usaben eran de nylon, vinylon, cloruro de polivinilideno y cloruro de polinivinilo, pero a partir de 1959 empezaron a usarse polietilenos y poliesteres y desde 1962 polipropileno. La exportación de redes de pesca de fibras sintéticas ha aumentado desde 400.000 libras en 1955 a unos 70 millones de libras en 1961, que se han enviado a más de 100 naciones. En 1961 se fabricaron de nylon y vinilon el 41 por ciento de las redes de fibras sintéticas, de polietileno el seis por ciento, de polivinilideno el cinco por ciento, de cloruro de polivinilo dos por ciento, de poliesteres el una por ciento y de fibras mixtas el cuatro por ciento. En cabos y cuerdas el vinilon representa el 53 por ciento y el polietileno el 23 por ciento. Se exporta casi toda la producción de cabos de fibras mixtas.

THE production of synthetic fibre fishing nets and ropes increased annually since its commencement in 1949, and 10 years later, in 1959, the output totalled some 25,000,000 lb of which 21,000,000 lb were used for manufacturing fishing nets. The production is estimated to increase further in 1962 to some 45,000,000 lb of which 32,000,000 lb are expected to be used for fishing nets.

The 1949 output of natural fibre fishing nets, lines and ropes—cotton, hemp, and silk products—totalled some 216,000,000 lb of which 28,000,000 lb were used in

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For trawls the material has certain obvious advantages such as hairiness and relatively large knot size so that more fish may be retained at a given mesh size than in equivalent continuous multifilament 'Ulstron' trawls.

Conclusion

Nylon, with its outstanding advantage of high strength, was introduced to the fishing industry just after World War II. Polyester with its better resistance to stretching, was added to the fishermen's resources some five years later and polythene followed at a similar interval having the advantage of being lighter than both.

With the introduction of 'Ulstron' polypropylene, the fishing industry now has a synthetic fibre which to a large measure combines the outstanding properties of all these three groups which have formerly been used to meet the exacting requirements of the fisherman.

Appendix: Trademarks

U'lstron', 'Terylene', 'Dispersol' and 'Duranol' are registered trademarks, the property of Imperial Chemical Industries Limited.

'Supracet' is a registered trademark, the property of L. B. Holliday and Co. Ltd., Huddersfield, England.

'Foron' is a registered trademark, the property of Sandoz AG. Lichtstrasse 35, Basle, Switzerland.

'Resolin' is a registered trademark, the property of Farbenfabriken Bayer Aktiengesellschaft, Leverkusen, Federal Republic of Germany.

'Serisol' is a registered trademark, the property of Yorkshire Dyewares and Chemical Co., Kirkstall Road, Leeds, 3, England.

'Cibacet' is a registered trademark, the property of Ciba AG. Klybeckstrasse 141, Basle, Switzerland.

'Systron' is a registered trademark, the property of Wrights Ropes Ltd., Universe Works, Birmingham 9, England.

'Vinamul' is a registered trademark, the property of Vinyl Products Ltd., Carshalton, Surrey, England.

'Cuprinol' is a registered trademark, the property of Cuprinol Ltd., 7 Upper Belgrave Street, London, S.W.1., England.

fishing nets. The output dropped to 94,000,000 lb in 1962, only 3,000,000 lb were used for fishing net manufacture.

At present nearly 85 per cent of the total fisheries need is met by synthetic fibre nets.

In early days, synthetic fibre nets and ropes were made principally of nylon, vinylon, polyvinylidene chloride and polyvinyl chloride fibres. In 1959, however, polyethylene and polyester fibres were added and, in 1962, polypropylene fibre joined the ranks of materials for manufacturing fishing nets. The use of combinations of fibres began in 1955.

While the demand for fishing nets is increasing, principally for export, demands for ropes and the replacement of manila ropes with those of synthetic fibres have also risen steadily.

In 1955, exports of synthetic fibre fishing nets totalled 400,000 lb but by 1961 the amount jumped to some 70,000,000 lb which were shipped to more than 100 nations.

Production

Fluctuations in production of synthetic fibre fishing nets and ropes are shown in Table I.

TABLE I—Production of synthetic fibre nets and ropes

In 1,000 lb		1955	1960	1961
Nylon	Net	3,535	9,293	12,749
	Rope	101	651	1,241
	Total	3,636	9,944	13,990
Vinylon	Net	3,890	11,953	12,679
	Rope	337	3,179	5,342
	Total	4,227	15,132	18,021
Polyvinylidene Chloride	Net	1,148	1,415	1,393
	Rope	128	110	194
	Total	1,276	1,525	1,587
Polyvinyl Chloride	Net	—	911	574
	Rope	—	332	645
	Total	—	1,243	1,219
Polyester	Net	—	—	238
	Rope	—	—	354
	Total	—	—	592
Polyethylene	Net	—	—	1,716
	Rope	—	—	2,363
	Total	—	—	4,079
Twisted blended	Net	42	1,399	1,333
	Rope	—	—	7
	Total	42	1,399	1,340
Total	Net	8,615	24,971	30,682
	Rope	566	4,272	10,146
	Total	9,181	29,243	40,828
(Reference) Natural Fibre	Net	24,781	10,182	4,413
	Rope	66,935	87,259	98,987
	Total	91,716	97,441	103,400

A review for 1961 reveals that, for fishing nets, nylon and vinylon each accounted for 41 per cent; polyethylene fibre for six per cent; polyvinylidene fibre for five per cent; polyvinyl chloride fibre for two per cent; polyester fibre for one per cent; and blended fibres accounted for four per cent. It is evident that the majority of fishing nets is made of nylon and vinylon. In ropes and lines (longlines and those for land use included), vinylon accounts for 53 per cent; polyethylene fibre for 23 per cent; nylon for 12 per cent; polyvinyl chloride fibre for six per cent; polyester fibre for four per cent; polyvinylidene fibre for two per cent, showing the importance of vinylon, nylon and polyethylene in this field.

Combinations of fibres are comprised principally of nylon and vinylon, nylon and polyvinylidene, and nylon and polyvinyl chloride fibres. Almost the entire output of ropes of blended fibres is exported.

Production of synthetic fibre fishing nets is expected to expand steadily in future, as in the past, but even greater increase of rope production is expected. The output of natural fibre ropes in 1962 has shown a decrease of some 7,000,000 lb from the preceding year, but the synthetic fibre rope output has increased some 1,000,000 lb, thus showing a progress in replacing manila ropes with synthetic fibre ropes.

The principal uses of fishing nets made of different synthetic fibres are shown in Table II.

TABLE II—Principal uses of synthetic fibre

Uses
Nylon: Gillnet, round haul net, longlines, various ropes
Vinylon: Round haul net, setnet, gillnet, longlines, trawlnet and other small dragnets, various ropes
Polyvinylidene Chloride: Setnet, trawlnet and other small dragnets, various ropes
Polyvinyl Chloride: Setnet, trawlnet and other small dragnets, various ropes
Polyester: Longlines, various ropes
Polyethylene: Various ropes, gillnet, trawlnet and other small dragnets
Polypropylene: Gillnet, various ropes.

Exports

Expansion of export of synthetic fibre products is notable—see Table III. Nylon accounted for 60 per cent of the total, while vinylon accounted for 21 per cent and blended fibres for 12 per cent. These products are shipped to more than 100 nations, with South-east Asia, Africa and North America as the principal markets. Others importing Japanese fishing nets and ropes in large quantities include Thailand, Pakistan, Malaya, the United States, Canada and Iceland.

TABLE III—Exports of synthetic fibre nets and ropes

In 1,000 lb	1955	1960	1961
Nylon	264	3,901	6,191
Vinylon	77	1,617	2,233
Polyvinylidene Chloride	—	29	141
Polyvinyl Chloride	—	238	387
Polyester Fibres	—	26	64
Polyethylene Fibres	—	2	266
Twisted blended yarn	42	1,393	1,327
Total	383	7,206	10,609

New synthetic fibres

New synthetic fibres used for fishing nets include polyethylene and polyester fibres, which were adopted in 1959, and polypropylene fibres first used in 1962. Among the three types of fibres, polyethylene is used in greatest quantity, while polyester and polypropylene fibres are still in an experimental stage. Polyethylene and polypropylene fibres are characterised by high tenacity and low specific gravity, while polyester fibre is outstanding for its high resistance against wear and tear.

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Production and Characteristics of Synthetic Nets and Ropes in Japan

Abstract

The paper reviews the production and consumption of synthetic materials in Japan and tries to clarify some of the technological problems regarding their rational use. The total amount of webbing and ropes presently used in Japan is about 87,000 tons. Webbings: 27,000 tons of which 90 per cent synthetic. The conversion has been more complete for netting than for ropes as only about 19 per cent of the ropes in use are of synthetic fibres. Summing up, the paper gives the characteristics of the various synthetic materials, supported by numerous tables. The main requirements for various fishing gears are then discussed. For fixed trap nets twines are required which have a high initial weight in water and smooth surface texture to give a minimum resistance to the current; tarred polyvinyl alcohol is sometimes preferred. For purse seines which also need a high sinking speed, twines of at least two g/den loop strength are required, and tarred nylon is mainly used. For the straight gilling types of gillnets, such as sardine nets, the Japanese fishermen prefer polyvinyl alcohol yarn. For other gillnets the polyamide and polyester groups are generally used. For bottom trawls nylon and vinylon normally have been used but polyethylene and polypropylene are gaining ground. However, due to the cost of synthetics, the extensive wear and occasional loss of such nets, the Japanese fishermen often use natural fibres when towing on a rough bottom especially for the underparts of trawls. One of the reasons why manila rope is largely preferred by the fishermen is its low elongation (12 to 20 per cent) as compared with 25 to 50 per cent of synthetic fibre ropes. Recent production of ropes made of mixed materials and subsequent treatment with resin has improved the handling of polyethylene ropes but further improvements to rope-making techniques are required before synthetic material ropes may be fully exploited in fisheries. Monofilament gillnets are said to have a 1·2 to 2·3 times higher catch ratio than other types of twine; nevertheless, these nets present difficulties in bulkiness and knot-fastness, and further research and development is required.

by

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Production et caracteristiques des cordes et filets synthétiques au Japon

Résumé

La communication traite de la production et de la consommation de matériaux synthétiques au Japon et essaie d'éclaircir certains problèmes technologiques concernant leur utilisation rationelle. Sur 87,000 tonnes de filets et cordes utilisés au Japon, environ 90 pour cent sont de matériaux synthétiques. La conversion a été plus complète pour les filets que pour les cordes dont 19 pour cent seulement sont en fibres synthétiques. La communication contient également de nombreux tableaux donnant les caractéristiques des différents matériaux synthétiques utilisés ainsi que les principales conditions requises par divers engins de pêche. Pour les trappes fixes, les fils doivent être lourds et avoir une surface lisse afin d'offrir le minimum de résistance au courant; le polyvinyl alcohol goudronné était préféré jusqu'ici. Pour les sennes coulissantes, une grande vitesse de coulée et des fils ayant au moins deux gr/d de résistance en mailles sont nécessaires et le nylon goudronné est le plus utilisé. Pour les filets maillants tels que les sardinières, les pêcheurs Japonais préfèrent les fils de polyvinyl alcohol; pour les autres filets, ils emploient généralement le polyamide et le polyester. Pour les chaluts de fond, le nylon a été normalement utilisé mais le polyéthylène et le polypropylène gagnent du terrain. Cependant, étant donné le prix élevé des fibres synthétiques, l'usure excessive et les pertes occasionnelles de ces filets, les pêcheurs Japonais utilisent souvent des fibres naturelles, particulièrement pour le dessus des chaluts. Ils préfèrent aussi les cordes de manille dont l'élongation (12 à 20 pour cent) est très faible comparée à celle des cordes synthétiques (25 à 50 pour cent). Une récente production de cordes faites de matériaux mixtes puis traitées avec de la résine, a amélioré la manipulation des cordes de polyéthylène, mais d'autres améliorations dans les techniques de fabrication des cordes seront nécessaires avant que la pêche puisse exploiter complètement les cordes faites de fibres synthétiques. Les filets maillants en monofilaments sont sensés avoir un coefficient de capture supérieur de 1·2 à 2·3 à celui des autres fils, mais ils sont trop volumineux, leurs noeuds manquent de stabilité et leur développement requiert de plus amples recherches.

Produccion y caracteristicas de redes y cables sintéticos fabricados en el Japón

Extracto

Reseña el autor la producción y consumo de materiales sintéticos en el Japón y aclara algunos de los problemas tecnológicos que plantea su uso racional. Actualmente en el pais se emplean unas 87,000 tons de paños y cables, el 90 por ciento de los cuales es de materiales sintéticos. La transformación ha sido más completa en el caso de las redes que en el de los cables pues solamente el 19 por ciento de los que se emplean actualmente es de fibras artificiales. Menciona el autor las caracteristicas de varios materiales sintéticos que las da en numerosas tablas. Discute las necesidades principales de los diversos equipos de pesca. Para las trampas fijas se necesitan hilos de mucho peso inicial en el agua y de superficies suaves para reducir la resistencia a la corriente; hasta ahora se ha mostrado predilección por el alcohol de polivinilo alquitranado. En el caso de las redes de cerco, que se tienen que hundir rápidamente, se necesitan hilos de, por lo menos, dos g/den y se usa principalmente nylon alquitranado. Para las redes que son principalmente agalleras, como los sardinales, los pescadores Japoneses prefieren hilos de alcohol de polivinilo; para otras redes de enmalle se usan generalmente poliamidos y poliésteres. Para los artes de arrastre de fondo se han usado normalmente redes de nylon, pero las de polietileno y polipropileno ganan terreno. Sin embargo, debido al costo de las redes sintéticas, su gran desgaste y pérdida ocasional, los pescadores Japoneses emplean con frecuencia fibras naturales, especialmente en las secciones inferiores de los artes de arrastre. Una de las razones

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Nearly 60 per cent of polyethylene output is used for manufacturing ropes, including floatline, buoyropes, seine net ropes, anchor ropes and guyropes. For ship use, towlines, hawsers, guyropes, lifelines and flaglines are made of these fibres. Fishing nets made of these fibres include trawlnets and other small drag-nets, fixed nets and round haul nets. Polyester fibre is used predominantly for manufacturing trawlnet ropes and longlines.

Polypropylene fibre manufacturing was limited last year to trial products, and is now being used in crab gillnets, round haul nets and ropes. Improvements in its weathering resistance, dyeability and abrasion resistance are likely to make it popular for manufacturing various types of fishing nets.

de que muestren tanta predilección por el abacá de Manila es su poco estiramiento (de 12 a 20 por ciento) con respecto al de las fibras sintéticas (de 25 a 50 por ciento). La fabricación reciente de cables de materiales mixtos y tratamiento posterior con resina ha mejorado la manipulación de los de polietileno, pero se tendrán que introducir otras mejoras en las técnicas de fabricación antes de que los cables sintéticos puedan aprovecharse completamente en la pesca. Se afirma que los artes de enmalle de monofilamentos pescan de 1·2 a 2·3 veces más que las de otras hilos, a pesar de lo cual su adopción no es universal porque son voluminosas y estan expuestas a que se corran los nudos, defectos que se tendrán que corregir mediante ulteriores investigaciones y perfeccionamientos.

THE total amount of netting and rope presently used in Japan is about 87,000 tons, an increase of 15,000 tons since 1940.

Of this tonnage an increasing volume is made from synthetic fibres as is shown in the range of tables on various aspects given in this article.

The rapid increase in local consumption is due to the expansion of high-sea fisheries. The local utilisation of synthetic fibre for fishing ropes is much less than for fishing nets. Out of an estimated 57,000 tons of rope in service in 1962, 10,688 tons (only 19 per cent) consisted of synthetic rope including the polyvinyl alcohol fibre used for longline and seine warps. The much slower conversion is due mainly to the low cost of manila which is about one-quarter the price of synthetic fibre.

Much care has been taken in assessing the best material for each particular fishery.

Fixed nets. Knotless nets and netting made of continuous heavy filament yarn are recommended. Resistance to sunlight should be high. Netting twines of polyvinylidene chloride and vinyl chloride groups have been mainly used. Polyvinyl alcohol has poor weather resistance and a low specific gravity but, to compensate, coal tar is often applied to those parts of the net receiving the main load or to the whole net when set in an area where the sea is generally rough. Nylon, though strong enough, is not very satisfactory as regards specific gravity and sunlight resistance and is furthermore too expensive.

The polyethylene group has low specific gravity (0·96) but is strong and not costly, and in black-coloured twines is adopted to make the upper parts of set nets. The black-coloured fibre stands up well to sunlight.

Purse seines. Optimal physical properties of webbing twines for purse seines: over 2·0 g/den in wet loop strength, 20 per cent in elongation, as well as high specific gravity. Knotless or weaver's knot webbings of nylon, vinylon and 'Tetoron' yarns are used in greater amounts for purse seines than for set nets. For the landing part of purse seines, however, fishermen prefer nylon or 'Tetoron' to vinylon even if they use vinylon for most of the other parts.

Sinking speed is important in purse seines and the amount of lead used for a nylon net is 30 to 40 per cent more than for a cotton net. The use of polyester group for purse seines is developing though these materials are rather costly. Tarring of the nylon and vinylon groups has increased the weight and sinking velocity of large-sized purse seines for skipjack, tunas, and mackerel, but this old technique cannot increase the specific gravity of a net.

Gillnets require invisibility in water, fineness and pliability, elasticity and abrasive resistance. Polyamide yarns are preferred for gillnets but some fishermen have turned to polyester yarn for large types of gillnets. Polyvinyl alcohol yarn, less fine, is mainly used for sardines.

Trawlnets. Even when nylon, polyethylene or polypropylene is used for other parts of a trawlnet, cotton or

Table I Cost ratio of fibre material to other materials used in fishing gear (1957)

Kind of gear	Fibre material			Other materials			Cost ratio $\left(\frac{A}{A+B} \times 100\right)$ (%)
	Item	Amount (Metric ton)	Cost (Yen)	Item	Amount (Number or Metric ton)	Cost (Yen)	
Fixed net for yellowtail 1957	Netting	19.6	5,660,000	Bamboo	2,163		93
	Ropes 1/	27.8	3,520,000	Glass floats	441	300,000	
	Other fibre materials	10.0	1,580,000	Straw bag	17,000		
				Dyestuff		480,000	
Two-boat trawl net (75.85 ton, 25 hp)	Netting	0.191	185,000	Glass floats	100	10,000	89
	Ropes	2.428	268,000	Trawl board	2	50,000	
				Others		40,000	
Two-boat purse seine for tuna and skipjack	Netting	8.894	12,800,000		(ton)		88
	Ropes	3.04		Leads	1.6	1,490,000	
	Other materials	1.0	1,400,000	Floats	0.5	420,000	
				Purse Rings	0.08	120,000	

1/ Wire rope is included in the fibre material as this may be replaced by fibre material in future.

vinylon webbings are used for under parts of the net because of their low cost. Fishermen have found it practical through experience not to use costly net materials, which are often lost when working rough grounds and this explains why cotton nets are still used side by side with polyamide, polyvinyl alcohol and polyethylene material.

Table II gives the following percentages of synthetic fibres used in various fishing gears by 1962:—

fixed nets—large 95, medium 85, small 70.
seine nets—purse seines 100, nuikiri ami (lampara type) 80, beach seine 70, others 90.
gillnets—for salmon 100, crab 95, sardine 90, herring 90, others 95.
dipnet—for suary 75, others 80.
trawl—other 100, two-boat 100, medium-sized 50, small-sized 45, others 45.
longline—oceanic tuna 100, coastal tuna 95, others 70.

Longlines. Comparative experiments conducted in regard to the tensile strength, elongation, and potential energy left in disused longlines of cotton and synthetic lines, indicate that vinylon line tested unknotted showed better characteristics than cotton line, whereas similar sizes of both lines when tested for loop strength did not always give comparable results in regard to the strength and potential energy. This implies that the loop strength is probably the best criterion for safe operation of longlines.

In the near future ropes mixed with polyethylene or polypropylene are likely to be preferred for the mainline of the longline gear, with improvement of the operation system, though the vinylon group has until now surpassed the other groups of synthetic fibres for the construction of tuna mainlines.

For the branchlines, polyester lines are preferred because of their high catch efficiency and their favourable characteristics of specific gravity, tenacity, and fineness.

Ropes. Cost of synthetic fibre ropes, over three times higher than manila rope, is one of the drawbacks. Another defect of synthetic fibre ropes in general is excessive elongation. In contrast to 12 to 20 per cent of manila ropes, synthetic fibre ropes are susceptible to as much as 25 to 50 per cent. This can make the ropes inefficient and sometimes even dangerous.

Table III—Fishing Gear synthetic fibres produced and exported

Fibre	Output in metric tons				Export in metric tons			
	1955	1957	1961	1962	1955	1957	1961	1962
Webbings								
Polyvinyl alcohol	1,768	3,368	5,763	5,505	26	320	495	502
Polyamide	1,607	2,783	5,792	6,592	74	1,286	2,466	4,111
Polyvinylidene chloride	572	631	633	461	7	5	38	31
Polyvinyl chloride	—	423	261	130	—	19	10	72
Mixtures*	19	695	606	797	—	652	315	619
Polyester	—	—	108	142	..	—	462	45
Polyethylene	—	—	780	719	—	—	—	—
Polypropylene	—	—	—	23	—	—	—	—
Sub Total	9,366	7,900	13,943	14,369	107	2,282	3,786	5,422
Ropes†								
Polyvinyl alcohol	152	690	2,428	3,320	12	4	260	235
Polyamide	46	103	564	885	5	—	75	105
Polyvinylidene chloride	58	109	88	194	—	2	4	—
Polyvinyl chloride	—	64	293	365	—	—	110	150
Mixtures	—	5	3	29	—	5	—	11
Polyester	—	—	161	55	--	—	—	8
Polyethylene	—	—	1,074	1,165	—	—	120	99
Polypropylene	—	—	—	15	—	-	—	—
Sub Total	256	971	4,611	6,028	17	11	569	608
Twines								
Polyvinyl alcohol	128	201	872	963	101	94	328	661
Polyamide	84	330	1,372	1,491	53	187	612	686
Polyvinylidene chloride	68	14	52	66	58	2	5	2
Polyvinyl chloride	13	58	90	135	—	23	16	54
Mixtures	—	20	99	154	--	19	85	120
Polyester	—	—	—	—	—	—	—	4
Polyethylene	—	—	554	620	—	—	140	141
Polypropylene	—	—	—	6	—	—	—	—
Sub Total	293	623	3,039	3,275	212	425	1,186	1,668
TOTAL	4,515	9,474	21,643	23,672	336	2,725	5,541	7,698

* Ropes made of mixed yarns of polyamide and polyvinylidene chloride or of polyvinyl chloride and polyamide.
† Includes materials for longline fisheries throughout.

Table IV—Local consumption of synthetic fibres for fishing gear

(Metric tons)	1961	1962
Fixed net		
Vinylon	732	651
Vinylidene chloride	490	343
Vinyl chloride	89	2
Polyethylene	—	—
Sub-total	1,311	996
Purse seine		
Nylon	903	538
Vinylon	1,709	1,866
Vinylidene chloride	61	34
Vinyl chloride	20	—
Combined	4	34
Sub-total	2,697	2,472
Gillnet		
Nylon	1,816	1,077
Vinylon	342	304
Vinyl chloride	10	—
Polyester	—	77
Polypropylene	—	18
Sub-total	2,168	1,476
Trawls and others		
Nylon	301	180
Vinylon	2,100	1,519
Vinylidene chloride	61	51
Vinyl chloride	79	2
Polyester	88	19
Polyethylene	707	534
Polypropylene	—	5
Combined	2	23
Sub-total	3,338	2,333
Ropes		
Nylon	525	780
Vinylon	2,293	3,085
Vinylidene chloride	45	194
Vinyl chloride	180	215
Polyester	152	47
Polyethylene	1,076	1,066
Polypropylene	—	15
Combined	—	18
Sub-total	4,271	5,420
Total of netting and ropes	12,785	12,697

All nets include twine used for constructing or mending.

Table V Tensile strength and elongation of various kinds of twine for comparable diameters

Kind of twine fibre	Construction of twine	No	Specific gravity	Diameter dry (mm)	Straight (wet) Tensile strength (Kg)	Straight (wet) Tensile strength (g/d)	Straight (wet) Elongation (%)	Trawler Knot (wet) Breaking Strength (Kg)	Trawler Knot (wet) Breaking Strength (g/d)	Trawler Knot (wet) Elongation (%)
Polyethylene A	Continuous 400d/F 9x3	10,800	0.96	1.84	52.2	4.83	25	65.1	3.01	19
Polyethylene B	Continuous 400d/F 9x3	10,800	0.96	1.83	49.4	4.57	17	70.5	3.27	15
Polyethylene C	Continuous 350d/F 10x3	10,500	0.96	1.80	49.7	4.73	15	40.4	1.92	13
Nylon 6	Continuous 210d/15F 20x3	12,600	1.14	1.80	63.8	5.06	36	75.6	3.00	32
Polyester	Continuous 250d 20x3	15,000	1.38	1.82	65.6	4.38	15	74.2	2.47	13
Polyvinyl chloride	Continuous 300d/60F 20x3	15,300	1.39	1.83	35.2	2.30	26	44.0	1.44	20
Polyvinylidene chloride	Continuous 360d/F 18x3	19,440	1.70	1.80	38.8	2.00	28	45.9	1.18	23
Polyvinyl alcohol	Staple 20's 15x3	11,700	1.26	1.79	36.6	3.13	32	42.8	1.73	26
Cotton	20's 16x3	12,480	1.52	1.82	28.8	2.31	33	47.5	1.86	28
Manila			1.45	1.90	39.0		13	52.5		12

Polyethylene A, B, and C differ in basic material as well as in manufacturing processes, according to producers.

The sample specimens were given a medium twist and tested under the following conditions: room temperature: 20 to 23°C, length of specimen: 60 cm, pulling velocity: 0.22 cm per second

Table VI—Number of major fishing gears by kind and size in Japan, 1960

Kind of gear	Small-type	Medium-type	Large-type
Fixed net	15,789	1,398	154
Purse seine	2,047	666	255
Trawlnet	3,379	1,911	806
Minor drag nets	13,186	226	—
Gillnet	49,692	2,738	230
Longline	30,953	2,287	1,412

Small-type nets are, in fixed nets, those operated by under 10 fishermen, and in other gears, those operated with non-powered boats or less than 10 GT.

Medium-type nets are, in fixed nets, those manned by 10 to 50 men, in other gears, those operated with boats from 10 to 50 GT.

Vinylon ropes are used greatly for warplines of Danish seine type of trawls seems because of their durability which is three to four times greater than that of manila ropes. Recently, a vinylon rope combined with wire came into existence for the warpline. Fishermen who employed this combination rope reported that the new warpline enabled them to operate more efficiently.

Polyethylene ropes are particularly suitable for the mainline of bottom longlines for cod and cod-like fish and for floatlines of salmon gillnets. Such ropes are very often twisted together with spun

Table VII Some properties of tuna longline

Name	Construction of lines	Diameter (mm)	Tensile strength (kg) (wet)	Elongation (%) (wet)	Main use
Cremona	20'S 50 x 3 x 3	6.00	265	46	Mainline Branchline
Cremona	20'S 55 x 3 x 3	6.10	290	47	"
Mansen	No.11(100d/F x 10 x 11 + 20'S 11 x 1)x3	6.00	315	59	"
Mansen	No.12(100d/F x 10 x 12 + 20'S 12 x 1)x3	6.40	345	48	"
Polyethylene	300d/F x 9 x 33	6.05	319	47	"
Nylon	210 d/15F x 36 x 33	4.55	355	65	Branchline
Tetoron	250 d/24F x 35 x 33	4.50	239	34	"
Mansen No. 9	(100 d/F x 10 x 9 + 20'S 9 x 1) x 3	5.3	250	53	"
Mansen No. 10	(100 d/F x 10 x 10 + 20'S 10 x 1)	5.7	285	52	"

Mansen is constructed with 100d of vinylon monofilaments where every 10 yarns is covered with vinylon spun yarn. Tetoron is a commercial name of polyester produced in Japan.

Table VIII Result of creep test and abrasion test of twines

Material	Relation between time (hour) and elongation (mm) when 2 g/d of load is given until creep occurs in twine											Frictions against steel edge 1/						Frictions against oil stone 2/
	Beginning	0.5	1	6	25	30	46	102	132	318	800 (hours)	load 10 (kg)			load 5 (kg)			load 0.5 (kg)
Polyethylene A	10.8		16.6	17.8			22.6	25.8	Creeping			16	22	17	85	101	93	0.71
" B	9.2		11.4	13.2			16.6	18.2	20.6	Creeping		9	9	9	82	78	81	0.84
" C	12.0		15.4	16.8			18.2	18.6	19.2	24.0	Creeping	19	20	22	142	156	174	0.89
Nylon	20.0	21.7		21.7	21.7	21.7	21.7			22.3	22.3 Creeping							0.70
Manila	3.0	3.3	4.0	4.0	4.3	4.7	Creeping						24			231		broken within 1,000 times of friction 3/
Cotton	7.0	7.3	7.3	7.3	7.3	Creeping												

1/ Angle of the steel edge is 90°. 2/ Wear strength against oil stone is represented by the ratio between the tensile strength after abrasing twine 5,000 times and the original strength. 3/ No comparable data available for these materials as they were broken before abrasing 1,000 times.

yarns of either 'Teviron' or vinylon in order to prevent slippage that may occur in handling them. The mixing rate of 'Teviron' or vinylon with polyethylene twines is from 10 to 30 per cent, depending upon the producers' or fishermen's requirements. Laboratory experiments indicated that the abrasion coefficient of polyethylene twines against oil stone was 0·18 to 0·20 as compared with 0·3 to 0·34 for spun yarn twines of 'Teviron' and vinylon, the former being more slippery than any other kind of synthetic twine.

Twisting together with other materials and subsequent treatments with resin has much improved the handling of polyethylene ropes.

Rope-processing techniques will require further improvement before synthetic fibre material ropes can be adopted for fishing rope to a greater extent.

Table IX gives abrasion coefficients for continuous filament netting twines by oil stone friction test.

Polyethylene 0·20, 'Amilan' (all nylon), 0·25 'Tevi-Ny' (partly nylon) 0·27, 'Kyokurin' (partly nylon) 0·28, 'Teviron' 0·28, 'Saran' 0·30, 'Kurehalon' 0·31.
Spun yarn: 'Kremona' 0·24, cotton 0·37 manila 0·41.

Japanese Fish Netting of Synthetic Fibres

Abstract

The total production of fishing nets in Japan for 1961 was approximately 9,000 tons; half of this was nylon. About 5,500 tons were for domestic use while about 3,500 tons were exported. Research on polypropylene fishing twines was recently undertaken and in 1962 several firms started industrial production. Tests on the polypropylene fibres produced in Japan showed that it is stronger than polyamide 6 for the same denier and has a higher degree of toughness. It is, however, stiffer and more bulky which, at present, seems a disadvantage in its use as gillnet material. However, development continues and indications are that this fibre should produce equal if not superior quality fishing twines. The heat treatment used on synthetic yarns is aimed at reducing elasticity and increasing strength; such treatment applied to twines is aimed at stabilising the twist, while the heat treatment of netting is directed toward heat-setting the knots. Most heat-treatment methods can be classified under either the dry or the wet systems, although some methods use both. Several methods have been evolved using electricity, chemical baths and even high-frequency. The latest innovation is based on heat radiation and makes use of ultra-red lamps. The boiling water treatment of the early days has long since been superseded by the use of steam or other heated vapours. Liquid treatment, however, has the advantage that it avoids all risk of overheating as the temperature of the bath can be fully controlled. A major point in all heat treatment is that the shrinkage which accompanies all such treatments must be within the range of the specific elongation of the material.

Filets de pêche Japonais, en fibres synthétiques

Résumé

La production totale de filets au Japon pour 1961 était approximativement de 9.000 tonnes dont la moitié étaient de nylon. Environ 5.500 tonnes étaient destinées à l'utilisation domestique et 3.500 tonnes, à l'exportation. Des études sur les fils de polypropylène ont été entreprises récemment, et en 1962, plusieurs firmes en commençaient la production industrielle. Les épreuves des propriétés du polypropylène produit au Japon ont montré que sa résistance à la rupture était plus grande que celle du polyamide 6 pour un même denier et que le polypropylène était aussi plus tenace. Le polypropylène par contre est plus raide et plus encombrant ce qui, à présent, constitue un désavantage pour son emploi comme matériau de filets maillants. Cependant le développement continue et il semble que cette fibre pourra produire des fils de qualité supérieure. Le but du traitement par la chaleur utilisé pour les fils synthétiques est de réduire l'élasticité et accroître la résistance à la rupture. Un même traitement appliqué aux fils retordus permettra de stabiliser le retordage tandis que ce traitement appliqué aux filets fixera les noeuds. Les différentes méthodes de traitement peuvent être classées dans deux groupes: le système "sec" ou le système "mouillé" bien que certaines méthodes utilisent les deux systèmes. Plusieurs méthodes utilisent l'électricité, les bains chimiques et meme du courant à haute fréquence. La dernière innovation est basée sur l'irradiation de la chaleur à partir de lampes à rayons ultra-rouges. L'eau bouillante des premiers temps a été remplacée par la vapeur chauffée.

Redes de pesca Japonesas de fibras sinteticas

Extracto

En Japón en 1961 se fabricaron cerca de 9.000 toneladas de redes de pesca; la mitad eran de nylon. Unas 5.500 tons las absorbió el mercado interno y unas 3.500 tons se exportaron. Recientemente se inició la investigación de los hilos de polipropileno para redes de pesca y en 1962 varias empresas iniciaron la producción industrial. Los ensayos de las fibras de polipropileno fabricadas en Japón demuestran que a igualdad de denier son más robustas y duraderas que las de poliamido 6, pero también son más rígidas y voluminosas, lo que actualmente parece ser un inconveniente para su empleo en los artes de enmalle. Continúan los estudios y las indicaciones son que con esta fibra se obtendrán hilos iguales o superiores. El tratamiento térmico reduce la elasticidad e incrementa la robustez de las hilazas sintéticas: estabiliza la torsión de los hilos y fija los nudos de las redes. Casi todos los tratamientos térmicos pueden clasificarse como secos o húmedos, aunque en algunos casos se emplean ambos. Se recurre también a la electricadad, baños químicos e incluso la alta frecuencia. La más reciente innovación se basa en la termoradiación de las lámparas de rayos ultra-rojos. Los baños en agua hirviendo de los primeros días han sido sustituídos por el empleo de vapores de agua u otros supercalentados. El tratamiento líquido tiene la ventaja de que evita todo peligro de sobrecalentamiento porqu la temperatura del baño puede regularse exactamente. Un factor de la mayor importancia en todos los tratamientos térmicos es que el líncogimiento que los acompaña tiene que quedar dentro de los emites del estiramiento específico del material.

by

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Japan Synthetic Fibre Net and Rope Association

SYNTHETIC fibres used in the manufacture of fishing nets in Japan are:

Group	Type	Some brand names
Polyamide	Nylon 6	'Amilan' and 'Grilon'
Polyvinyl alcohol	Vinylon	'Manryo', 'Kuralon', 'Kremona' 'Mewlon'
Polyvinylidene	Vinylidene	'Saran', 'Kurehalon'
Polyvinyl chloride		'Teviron', 'Envilon'
Polyester		'Tetoron'
Polyethylene		'Hi-Zex', 'Pylen-E', 'Ethylon'
Polypropylene		'Pylene'

These fishing twines are each made up of one-fibre material. Twines made up of a combination of yarns or fibres of different fibre materials are also produced, mostly with nylon as the basic material, although twines are available with vinylon as the basic material with other fibres twisted in.

Total production of fishing nets in Japan for 1961 was approximately 9,000 tons; half being nylon. About 3,500 tons were exported, the balance being for domestic use.

The numbering systems presently used in Japan are not officially established and are for business dealings only.

The quality standards of Japanese twines and nets for use within the country are covered by the Japanese Industrial Standards (JIS) which has been set up by the Ministry of International Trade and Industry. These standards comprise the following:

JIS L 1033-58	Testing method for vinylon spun plied yarn for fishing net
JIS L 1034-58	Testing method for filament nylon plied yarn for fishing net
JIS L 1035-58	Testing method for filament vinylidene chloride yarn and filament vinylchloride plied yarn for fishing net

JIS L 1043-58 Testing method for synthetic fibre for fishing net

The JIS further comprises inspection standards for the use of net manufacturers as quality norms for their product intended for export.

Polypropylene

Polypropylene fibres industrial production only started in 1962. There is therefore very little experience of it as a netting twine.

It is presently produced by two different techniques—that introduced by Montecatini of Italy, and by the Abisun Corporation of U.S.A. Eight firms have started manufacture with a total production capacity of 38 tons per day.

The technique used in spinning, dyeing and general manufacture of polypropylene filament differs from one manufacturer to another.

TABLE I—Average characteristics of Japanese polypropylene

		Polypropylene filament 180d (20·24 f)	Polypropylene spun No. 20S
Specific gravity		0·91	0·91
Tenacity (g/den)	Dry	6·5—7·7	4·3—4·5
	Wet	6·5—7·7	4·3—4·5
Extensibility, straight (%)	Dry	20·5	16·0—16·5
	Wet	20·5	16·0—16·5
Loop strength (g/den)	Dry	4·8—5·3	3·4—3·6
	Wet	4·8—5·3	3·4—3·6
Decrease of strength caused by knotting (%)		28·0	20·0
Wet breaking strength (kg/mm^2)	Straight	53—63	35—37
	Loop	40—43	28—30
Moisture absorption (%)		0·1	

The study and research on polypropylene filament and twines for netmaking is continuing and there are indications that, with more experience, twines will be produced of equal if not superior qualities to other synthetic fibres. The fibre has unique features and characteristics which have already proved to a certain extent that it can be used to advantage for the manufacture of twines and ropes. There are, however, a few problems to be overcome.

Heat treatment

Heat treatment of synthetic netting twines varies according to the kind of fibre, twine count, type of knot and the end-use intended. Some synthetic fibres do not require any heat-setting.

Heat treatment is applied for three main reasons: (a) Twist-setting of twine; (b) Setting of knots in netting; (c) Stabilising the shape of meshes.

It is primarily aimed at reducing the extensibility and at increasing the strength of twines although, at the same time, it sets the twist in the twine. There are many methods for heat-setting and a variety of devices are in use. For certain fibres heat treatment is more difficult than for others and only heat treatment of nylon netting is considered here.

There seems no theoretical or scientific principle for establishing an optimum heat treatment method. The techniques in use have been developed and improved by practical experience, while new methods and new devices are continually introduced.

Early heat treatment processes were mainly intended to obtain an "ironing" effect, and usually consisted of heating and pressing at the same time.

The first 'Amilan' netting twines (type 100) were heat treated by the "heated ironplate" system. The apparatus consists of a chamber with a heated ironplate on top. This heated chamber contains 'Anilene' or ethylene glycol, and the webbing is run through it. 'Amilan' softens at 180°C, so the heat should be kept below this point.

This treatment is expensive and can only be used for twines of 210d/6 and finer.

To heat treat coarser twines than 210d/6, a new type of 'Amilan', type 300, was developed. This type did not prove successful for gillnet twines, being too extensible. The next 'Amilan' yarn was of type 700 with a very low extensibility and it proved excellent for all types of gillnets.

Heat-treatment methods are of two types—dry and wet. Sometimes both methods are incorporated in one type of heat treatment, so that the so-called dry system also uses water steam. The dry system is mostly used by net manufacturers while the wet system is mainly applied to yarns and twines.

The method and the construction of the necessary equipment vary according to production capacity, type of nets and nature of heat used. Various methods, based on heat conduction, use either electric regulators, 'Anilene' baths, melamin-resin, metal baths or high-frequency.

A different principle is heat radiation by, for example, the use of ultra-red lamps. Here the net is run over the radiating elements or alternatively the element is passed over the netting. In general this method has not proved very effective.

One heat-treatment method used largely in early days was to run the nets through boiling water, but today's wet-treatment systems all make use of water steam or other vapours.

Treatment with liquid, such as boiling water, has a big advantage in that it avoids the risk of over-heating. Nylon, which shrinks in boiling water, lends itself well to this treatment for setting knots.

Twines usually require heat-setting to reduce their extensibility and increase the strength, whereas heat treatment is normally aimed at setting the knots in the nets; in both cases, however, the heat should be applied while the material is under tension. For nets, this is normally obtained by running them between friction rollers, which furthermore help to reduce irregularities in the braiding and at the same time pre-set the knots firmly. The tension to be applied should be chosen

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New Synthetic Herring Driftnets Used in the North Sea

Abstract

In driftnetting the technique and nets differ from area to area and even between the nationals operating them, due to the peculiar traditional habits of the fishermen themselves. Experiments carried out using a great variety of net constructions made of polyamide ('Perlon', 'Steelon', 'Dederon'), polyvinyl alcohol ('Kuralon') and cotton, showed that while polyamide is by far the strongest material, polyvinyl alcohol lends itself better for herring driftnetting due to less damage to the fish. Notwithstanding, it was observed that all synthetic materials must be stiffened to avoid damage to the herring while shaking out. Two years of subsequent commercial fishing with 'Kuralon' nets have shown that while their catch efficiency is equivalent to that of cotton nets, they need only one-fifth as much replacement for loss and damage. By the end of 1962, more than 2,000 'Kuralon' driftnets were in commercial use compared to 8,000 cotton driftnets showing that Polish fishermen are now turning over to synthetic materials for the driftnet fishery.

by

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Nouveaux matériaux synthétiques utilises dans la pêche au hareng en mer du nord

Résumé

La technique de la pêche au filet maillant diffère solon le lieu et même la nationalité des opérateurs, différence dûe aux habitudes traditionnelles particulières des pêcheurs eux-mêmes. Des essais effectués avec des filets de constructions très variées, faits de polyamide ('Perlon', 'Steelon', 'Dederon'), de polyvinyl alcohol ('Kuralon') et de coton, ont montré que bien que le polyamide soit le plus fort des matériaux le polyvinyl alcohol est meilleur pour fabriquer des filets maillants pour le hareng parce qu'il endommage moins les poissons. Cependant on a pu observer que tous les matériaux synthétiques doivent être durcis pour qu'ils n'abîment pas les harengs lorsqu'on secoue les filets. Deux années de pêche commerciale avec des filets maillants faits en 'Kuralon' ont montré que leur efficacité de capture est équivalente à celle des filets en coton et ne doivent être remplacés pour perte ou détérioration que dans la proportion d'un cinquième. A la fin de 1962, plus de 2000 filets maillants en 'Kuralon' étaient employés commercialement contre 8000 en coton, ce qui démontre que les pêcheurs polynésions commencent maintenant à utiliser les matériaux synthétiques pour la pêche du hareng au filet maillant.

Nuevos materiales sinteticos para las redes de deriva arenqueras usadas en el mar del norte

Extracto

En la pesca a la deriva, la técnica ya las redes varían de un país a otro incluso dentro del mismo país debido a las peculiaridades tradicionales de los pescadores. Los experimentos realizados con muchas redes de poliamidos ('Perlon, 'Steelon', 'Dederon'), alcohol de polivinilo ('Kuralon') y algodón, demostraron que

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according to type of fibre and size of material, mesh size and volume of netting.

Very often, a resin product is applied to set the knots firmly.

Treatment of 'Amilan' nets

For heat-setting of salmon gillnetting, this procedure is general:

(a) As the net comes from the braiding machine, it is passed through a resin solution or polyvinyl alcohol and is wound on a roller. During winding the netting is pressed to prevent loosening of the knots.

(b) The netting is then passed in a stretching machine to tighten the knots. While under stress, the netting passes through a vacuum pipe which enhances the heat conductivity of the material.

(c) After stretching, the webbing is usually inspected and, if necessary, mended.

(d) A steel bar is inserted in the meshes at both ends of the section immersed in the boiling water, and force is applied to the bars in accordance with the amount of stretch required.

The maximum extensibility of 'Amilan' netting is 17 to 20 per cent and netting of 210d/12 should be stretched while under treatment 13 to 14 per cent of its original length.

Steam can be applied as heating agent but the material should not come into contact with it. The webbing is run through a steel-plate box while the steam passes through the double wall of this box and heats the air in the chamber, where the webbing is run.

Another method is to run the webbing, in firm contact, over the heated surface of a hotplate. Tensionless heat treatment in resin emulsion at a temperature of 90 to 100°C is still another method.

Dyeing

Nets are normally dyed after drying, and dyeing should take place only after the net has been thoroughly washed and all chemicals used removed. One recent method applies the dye automatically, by spraying to the net while it passes through a dye-beck. Such dyes are complex in composition and are normally applied by a special process so that the dye permeates and reaches the filaments of individual twines.

After dyeing, a resin treatment is sometimes applied; either urea-resin or thermoplastic resin may be used; the latter enhances the effect of dyeing. After such treatment, the net is usually stretched and dried for about five minutes at a temperature of 150 to 160°C.

aunque los poliamidos son, con mucho, los más robustos, el alcohol de polivinilo es más a propósito para la pesca a la deriva del arenque porque perjudica menos al pescado. También se observó que a todos los materiales sintéticos hay que darles rigidez para evitar que estropeen al arenque cuando se sacuden. Dos años de pesca industrial con redes de 'Kuralon' han demostrado que su rendimiento de pesca es equivalente al de las redes de algodón, pero que las averías y pérdidas se reducen a la quinta parte. Para fines de 1962, los pescadores polacos empleaban 2.000 redes de deriva de 'Kuralon' y 8.000 de algodon, lo que demuestra que adoptan los materiales sintéticos para dichas redes.

FISHING techniques and gear differ from area to area even though they have been developed for catching the same species of fish. This is partly due to the different types of vessels used by different nations but is also due to the peculiar traditional habits of the fishermen themselves. The same applies to the mechanisation and modernisation of boats and gear for different communities, in spite of the fact that such communities operate the same areas for the same species and are in close contact with one another.

Herring driftnetting, operated for ages by Dutch, British, German and Polish fleets, are all carried out simultaneously for the same species and one could expect that the gear would have developed one standard type. But this is not so and investigation shows the basic purpose is different. For most driftnets used it would seem the main purpose has been to construct strong and durable nets; with cotton nets numerous and costly preservation treatments are necessary to prolong working life and even with conversion to synthetic materials, this purpose seems to have been maintained. In other words, Dutch experiments with nylon herring driftnets seem to be entirely directed towards producing more durable gear.

The purpose behind the driftnets used by the Soviet herring fleets is vastly different as the nets are made of cheap and remarkably thin cotton yarn of only average quality, with all lines made of hemp. Although the nets are treated with a preservative they are designed to be discarded after one fishing season. This, of course, saves repeated preservative treatment and storage between seasons. The reason is probably plenty of cheap cotton.

Since countries such as Poland do not have their own source of cheap natural materials, efforts to modernise the herring gillnets by replacing cotton materials with synthetics are necessary, so Polish experiments have aimed at determining the best type of synthetic material to use.

The need for synthetic gillnets in Polish fisheries is also based on the practice of trawler-drifters to switch from gillnets to trawls and vice versa. In these circumstances, cotton gillnets, even though well preserved, were frequently found to deteriorate after only a few days storage. The first small-scale experiments were initiated in 1956, and now over 2,000 synthetic gillnets are used in Polish fisheries.

Experiments to date have resulted in the use of synthetic nets with sisal lines. Their superiority over cotton gillnets has been proved but it is still felt that gillnets made entirely of synthetics would be more desirable.

Materials and methods

Even though synthetics such as the polyamide or polyvinyl alcohol fibres are well known, they are still not used in certain types of gear. The Material Research Section of the Laboratory of the Sea Fisheries Institute, Gydnia, Poland, selected two basic types of synthetic products: the polyamide group ('Steelon', 'Perlon', 'Dederon') and the polyvinyl alcohol group ('Kuralon') for experiments, aimed at developing synthetic driftnets for the drifter-trawler fleet. The technical data of these materials, as well as for the cotton (used as a control), is given in Table I which is linked with Table II.

The coefficient of change in mesh size was calculated by the formula:

$$Ww = \frac{100\,a}{2b}$$

Where Ww is the coefficient of change in mesh size.
a is the elongation of the mesh at break in mm
b the barlength plus one knot (mesh size).

The coefficient of the mesh stability in connection with the percentage of untied meshes during the mechanical analysis, gives an indication of the probable behaviour of each material during actual fishing operations. The coefficient of stability Wt of the mesh is evaluated by the formula:

$$Wt = 100 - R\left(\frac{Ws - Wo}{Ws}\right)$$

where Ws is the mean mesh breaking strength
Wo is the mean strength of the meshes untied during the analysis
R is the percentage of meshes untied during the analysis
R is obtained from the dependence

$$R = \frac{I_s}{I + I_s}$$

where I is the number of breakings in the analysis which served to evaluate the mean breaking strength
I_s is the number of untied meshes during the experiment.

The yarn diameter was measured with a thickness gauge with accuracy of 0·01 mm with an initial charge of 50 g.

The investigations were carried out during two voyages, each lasting for about two months.

Eighty experimental driftnets were made of these materials for the first voyage and 110 for the second.

Experimental nets were constructed to the same design and specifications as those successfully used by all western nations fishing herring in the North Sea. The net sections consisted of a central panel of 780 meshes long and 340 meshes wide, with 10 mesh wide selvedges made of thicker yarn. The webbing of the central panel and the side selvedges were hung so that the horizontal strain was "with the knots" while the upper and lower selvedges were hung so that the vertical strain was "with the knots" (see Fig. 1a).

In order to investigate if the arrangement of the netting and the selvedges have an influence on the practicable use, nets were made with the netting arranged in the different ways illustrated in Fig. 1.

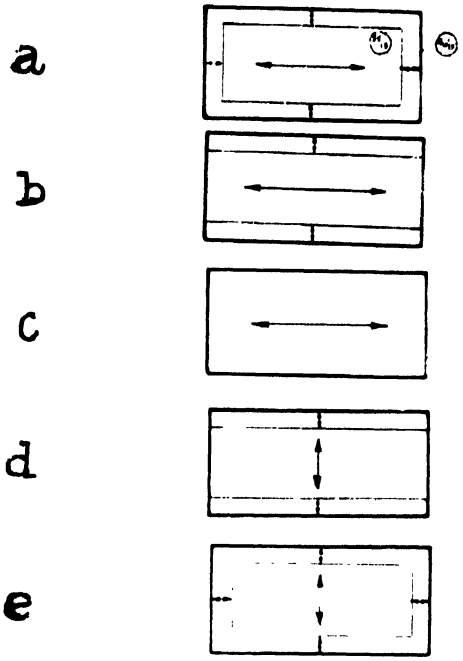

Fig. 1 Mesh direction arrangement of gillnets.

- **a normal arrangement**
- **b normal simplified**
- **c unstrengthened**
- **d simplified inverted**
- **e normal inverted**

The experiments were carried out on a typical commercial herring fishing vessel with a crew partly composed of scientists for recording the necessary data. Data recording during and after use of experimental nets included:

(a) Breaking strength of netting after the fishing period.
(b) Fishing yield for each type of gillnet.
(c) Estimation of the amount and the degree of damage to the fish.
(d) Estimation of the number of fish gilled.
(e) Degree of deterioration of the gillnets after the fishing period.
(f) Estimation of each particular type of net material for commercial use.
(g) Evaluation of work required of the crews for operating the different kinds of materials.

Experimental operations

The two experimental voyages lasted approximately two months each. The first one took place during October-November 1959, and the second in August-September 1960. Due to bad weather in 1959, the number of observations, experiments and measurements carried out were fewer than in 1960. About 40 operations during 1960 gave catches totalling 77 tons of herring compared to about 20 tons in 1959.

After each fishing operation samples of netting from all driftnets were analysed for mechanical strength and to define the eventual decrease in strength—see Table II (linked with Table I).

Polyamides have a relatively high strength, and the nettings of thinner yarns, e.g. 265 den/9 were nearly twice as strong as cotton netting; the thicker yarns of 265 den/12 were 2·5 times stronger than standard cotton ones.

The average strength of 'Kuralon' gillnets (omitting the badly chosen Nm 40/9) corresponds in general to the strength of high-quality cotton gillnets.

As indicated in Tables I and II, polyamide material has higher breaking strength than 'Kuralon', whose strength is near to that of the very good cotton. The mesh size of the experimental nets in 1959 was not suited to the mean size of the fish caught and the nets made of different materials had various mesh sizes. The nets in 1960 were all of more or less equal mesh size.

Table I

Technical data of herring driftnets used during the experiments

Material		Breaking strength in kg Dry	Wet	Diam	Meshsize Dry	Wet	Mesh change coefficient Dry	Wet	Mesh tenacity Dry	Wet	Percentage of broken meshes
Perlon	210 d/9	16.9	13.9	0.66	54	57	48.4	48.9	99.8	-	11
Perlon	265 d/9	15.4	14.2	0.82	44	46	58.7	55.1	99.9	99.8	6
Dederon	265 d/9	13.1	12.9	0.81	50	52	40.4	41.5	99.9	99.7	9
Dederon	265 d/9	15.6	14.-	0.88	51	52	46.1	43.4	99.9	99.9	-
Steelon	265 d/9	16.6	15.9	0.85	54	58	53.7	49.1	99.6	99.8	11
Steelon	265 d/9	15.5	14.1	-	51	53	48.5	49.3	99.5	99.3	25
Steelon	265 d/9	17.9	16.1	0.91	55	56	54.9	56.9	99.8	99.6	15
Steelon.	265 d/12	19.2	17.4	0.89	53	52	55.3	51.2	100	100	-
Steelon	265 d/12	22.4	19.9	1.07	54	56	57.6	54.2	100	100	-
Steelon	265 d/12	20.4	17.2	1.01	52	53	56.9	55.0	100	100	-
Steelon	265 d/12	22.2	21.6	1.13	50	52	68.9	66.4	100	100	-
Kuralon	Nm 40/9	6.1	4.9	0.66	52	51	40.0	49.0	100	100	1.5
Kuralon	Nm 54/15	7.2	5.9	0.83	54	51	43.0	43.1	99.5	99.8	5
Kuralon	Nm 54/15	8.0	7.1	0.89	51	50	57.9	54.2	100	100	-
Kuralon	Nm 40/15	8.7	7.5	0.97	57	52	57.7	67.5	99.6	99.7	5
Kuralon	Nm 40/15	9.7	8.9	1.04	54	52	80.1	79.2	100	100	-
Kuralon	Nm 20/9	8.3	6.6	0.80	53	52	37.2	36.8	100	100	-
Kuralon	Nm 20/9	9.9	8.1	0.90	53	48	51.1	49.7	100	100	-
Cotton	Nm 30/15	7.0	6.9	1.05	53	50	26.9	34.6	100	100	-
Cotton	Nm 54/15	7.9	8.3	0.85	54	54	36.5	44.2	100	100	-
Cotton	Nm 54/15	8.0	8.8	0.89	53	50	42.3	44.0	100	100	-

Table II

Technical specifications of materials used during 1959-60

Material		Breaking strength in kg Dry	Wet	Loss in strength through braiding Dry	Wet.	Meshsize in mm (1 k; pre-tension) Dry	Wet	Coefficient Meshsize Dry	Wet	Knotfastness Wet
Perlon	210 d/9	15.9	12.6	-12.6	-9.4	57	58	51.5	52.3	99.8
Perlon	265 d/9	15.3	13.9	-0.6	-2.1	45	47	58.7	56.2	99.8
Dederon	265 d/9	13.1	12.5	0	-3.1	49	52	46.0	50.9	99.7
Dederon	265 d/9	15.9	14.5	x1.9	x1.4	52	52	48.0	47.0	99.5
Steelon	265 d/9	16.5	14.1	-0.6	x1.4	55	59	50.0	50.9	99.7
Steelon	265 d/9	15.4	14.0	-0.6	-0.7	54	56	58.5	45.3	-
Steelon	265 d/9	17.1	15.8	-4.5	-1.9	56	56	52.7	50.9	100
Steelon.	265 d/12	18.2	16.4	-5.2	-5.7	54	56	51.9	47.3	100
Steelon	265 d/12	22.2	20.7	-0.9	x4.0	52	53	52.7	50.9	100
Steelon	265 d/12	20.2	17.8	-1.0	x2.3	54	53	50.9	54.5	100
Steelon	265 d/12	22.1	21.2	-0.5	-1.8	50	52	65.4	61.1	100
Kuralon	Nm 40/9	5.1	4.6	-16.4	-6.1	50	52	58.8	51.0	100
Kuralon	Nm 54/15	6.4	5.5	-11.0	-7.0	53	51	40.0	43.1	100
Kuralon	Nm 54/15	8.0	6.6	0	-7.0	52	49	50.0	55.1	100
Kuralon	Nm 40/15	7.8	7.1	-10.0	-5.0	54	52	56.0	66.0	100
Kuralon	Nm 40/15	9.6	8.3	-1.0	-7.0	50.	48	78.0	77.5	100
Kuralon	Nm 20/9	7.9	6.2	-4.8	-6.1	52	52	36.0	35.8	100
Kuralon	Nm 20/9	9.5	7.4	-6.0	--9.0	53	47	51.0	48.9	100
Cotton	Nm 30/15	6.8	6.5	-2.9	-5.8	55	50	25.8	31.6	100
Cotton	Nm 54/15	6.4	7.0	-19.0	-15.7	52	51	29.6	40.0	100
Cotton	Nm 54/15	8.0	8.1	0	-8.0	52	50	31.5	38.8	100

The mesh size of polyamide nets increased appreciably when wet, while the increase in the mesh size of 'Kuralon' nets was much less. The coefficient of change in mesh size is characteristic for the particular type of material and increases very much as a result of the tar treatment. The meshes of the untreated polyamide nets became easily distorted, causing considerable change in their dimension. It should be stressed that all the synthetic nets tested are commercially adaptable except those appearing as items 1 and 12 in Tables I and II.

Among examined materials, dyed 'Perlon' must be rejected for commercial use owing to its lack of mesh stability, and 'Kuralon' Nm 40/9 also because of insufficient initial strength.

Fishing efficiency

The most important factor is, of course, fishing efficiency. It also plays an important part in experimental catches in the interpretation of the obtained indices. However, due to the small number of operations carried out, no final conclusions concerning commercial possibilities can be drawn at this time.

The fishing results obtained with the different kinds of nets in both 1959 and 1960 are presented in Tables III and IV, and, as can be seen, the fishing results of all net types were, on average, satisfactory. The relatively low catches of some of the polyamide nets during the first experiment were caused by the mesh size of the nets being too large for the average size of the herring.

Table III First experiment

Fishing results of types of nets in 1959

Material & twine number	Treatment	Mean catch per net/day in kg.	Total fish per net in kg.
1.Perlon 265 d/9	dyed	15	85
2.Perlon 265 d/9	brown	45	270
3.Dederon 265 d/9	brown	30	210
4.Dederon 265 d/9	tarred	30	150
5.Steelon 265 d/9	caprolactam	15	70
6.Steelon 265 d/9	brown	20	110
7.Steelon 265 d/9	tarred	15	90
8.Kuralon Nm 40/9	brown	45	345
9.Cotton Nm 50/15	oil coated	35	215
10.Cotton Nm 54/15	chro-copper	30	195
11.Cotton Nm 54/15	tarred chro-cop.	25	140

When analysing the catch data per net per day, the mean catches of the polyamide nets reached 37 kg, of the 'Kuralon' nets 31 kg, and the cotton nets 31 kg. While the fish catches of driftnets depend highly on the proper choice of the mesh size, it is also important to obtain proper correlation between the fish size, the kind and thickness of the material and the quality of the net treatment.

The more soft the material, the higher its fish catching ability. This explains the high efficiency of untreated polyamide driftnets and the efficiency of thin 'Kuralon' driftnets. The thicker and stiffer the netting, the lower the efficiency. This can be seen from the tables but this conclusion is also based on additional observations mentioned later in the paper.

Type and degree of fish damage

The first experiments with polyamide driftnets in commercial lugger fisheries were failures. When Polish fishermen were given 'Steelon' nets of equal strength to the best cotton driftnets, they handed them back after only a few trials and reverted to the standard cotton nets. This emphasised the need for a detailed study of synthetic materials for driftnets as the future of the Polish lugger fisheries depend on developing better gear than the traditional cotton nets. The damage of the netting to the fish caused by the synthetic material, was partially responsible for this initial negative reaction

Table IV - second experiment

Fishing results of nets in 1960. Code: S = Steelon, K = Kuralon, C= Cotton, D = Dederon.

Material & twine number	Kind of finishing	Mean catch per net/day in kg.	Total fish per net in kg.
1.S 265 d/9	tarred	35	490
2.D 265 d/9	tarred	35	483
3.S 265 d/12	caprolactam	45	595
4.S 265 d/12	" + 2% tar	45	655
5.S 265 d/12	caprolactam 10%	25	333
6.S 265 d/12	caprol. + tar	35	462
7.K Nm 54/15	not finished	30	438
8.K Nm 54/15	tarred	30	385
9. K Nm 40/15	not finished	35	473
10.K Nm 40/15	tarred	25	333
11.K Nm 20/9	brown	25	315
12.K Nm 20/9	tarred	25	326
13.C Nm 54/15	chromate-copper	35	539
14.C Nm 54/15	" plus tar "	30	389

of the fishermen. In driftnets, the herring should be gilled strongly enough to prevent its falling out while the net is still in operation, but not so strongly that they are prevented from being easily shaken out during hauling. Too flexible a mesh causes damage to the fish which diminishes its value, and requires additional work from the crew. In this regard, cotton net gives a good performance and the tendency is to make nets of synthetic materials as much as possible similar to cotton nets. This can only be done by special physico-chemical treatment of the presently available synthetic material.

During 1959 and 1960, trials were made to define the influence of particular materials on the quality of the fish captured. The index was decided by taking the average percentage of damaged fish taken from each kind of gillnet. The results obtained are given in Table V and, as can be seen, there is a certain relation between the kind of material and the degree of damage to the fish. Polyamides, owing to their mechanical properties and especially their elasticity, are among the most gripping materials and consequently have the greatest percentage of damaged fish (more than 25 per cent).

The use of thicker and stiffer materials diminishes the percentage of damaged fish (see items 5 and 8 in Table V). The same result is obtained when the nets are treated with a stiffening preparation (see items 3, 4, 6, 7 and 9 in Table V). The simultaneous increase of the twine diameter and application of physico-chemical treatment reduces the percentage of damaged fish by the polyamide nets to that of the cotton nets.

This applies also to 'Kuralon' nets which, however, give a lower percentage of damaged fish in the untreated condition than polyamide. It suffices to select a proper thickness of 'Kuralon' twine to obtain even better average results than with cotton fabrics.

Table V Mean percentage of fish damaged after shaking for different kinds of driftnets. P = Perlon, D = Dederon S = Steelon, K = Kuralon, C = Cotton

Material & Twine Number,	diam mm	Treatment	Percent damaged fish
1. P 210 d/9	0.66	dyed	26.7
2. P 265 d/9	0.82	brown	12.9
3. D 265 d/9	0.81	brown	27.8
4. D 265 d/9	0.88	tarred	10.1
5. S 265 d/9	0.85	caprolactam	21.2
6. S 265 d/9	-	brown	23.5
7. S 265 d/9	0.91	tarred	9.4
8. S 265 d/12	0.89	caprolactam 2%	14.7
9. S 265 d/12	1.07	" + tar "	7.6
10. S 265 d/12	1.01	caprolactam 10%	5.2
11. S 265 d/12	1.13	" " + tar	6.4
12. K Nm 40/9	0.66	dyed	9.9
13. K Nm 54/15	0.83	untreated	9.0
14. K Nm 54/15	0.89	tarred	7.4
15. K Nm 40/15	0.97	untreated	4.6
16. K Nm 40/15	1.04	tarred	3.5
17. K Nm 20/9	0.80	brown	10.0
18. K Nm 20/9	0.90	tarred	9.0
19. C Nm 50/15	1.03	oil coated	6.6
20. C Nm 54/15	0.85	chromate-copper	6.0
21. C Nm 54/15	0.89	" " tarred	4.6

When determining the coefficient of damage to fish by the netting, we should stress that results may vary from ship to ship. For example, highly qualified crews may cause less damage by skilful handling of the nets during shaking, than inexperienced crews. It is most difficult to assess the damage caused by inefficient manipulation of the nets during shaking as the effect is combined with that of the gripping qualities of the material as well as the mesh size in relation to the girth-size of the fish. However, some indication can be obtained by the number of fish remaining gilled in nets of different materials after identical shaking. In Table VI the results obtained are reduced to a comparative scale with the chromate copper treated cotton nets as control. These indices again stress that the average performance of the driftnets depends on the accurate choice of the material and the mesh size.

Wearing rate of gillnets after fishing

After every voyage of comparable length to commercial voyages, a visual inspection of the gear was carried out by a group composed of skilful quality control inspectors. They assessed the necessity of repairs to the nets both as to quantity and quality, to restore it to full technical efficiency for the next voyage.

An estimation of the wear was based on the following conventional numerical scale used in Poland:

Table VI Quantity of fish remaining gilled after shaking

Material	Treatment	Index
Steelon	untreated or only dyed..	2.5 - 5
"	tarred	1.5 - 2.5
Kuralon	untreated or only dyed.	1.2 - 1.8
"	tarred	0.6-1.2
Cotton	chromate-copper preservation	1
Cotton	oil or tar coated	0.5 - 0.7

5—single small holes in the net.

10—numerous holes of several mesh sizes, single tears.

25—multidirectional tears of more than 10 meshes in length spread over the net, but not to the extent that replacement is necessary.

75—tears and holes such that only parts of the netting can be saved to patch others.

Table VII Estimation of mechanical wear of Driftnets P = Perlon, D = Dederon, S = Steelon, K = Kuralon, C = Cotton

Material & Twine Number	Treatment	Degree	Remarks
1. P 180 d/9	dyed	25	after two experimental voyages.
2. D 265 d/9	brown dyed	10	
3. D 265 d/9	tarred	5	
4. S 265 d/9	caprolactam	5	after two voyages.
5. S 265 d/9	brown dyed	10	
6. S 265 d/9	tarred	5	
7. S 265 d/12	caprolactam 2%	5	
8. S 265 d/12	" + tar	0	
9. S 265 d/12	caprolactam 10%	5	
10. S 265 d/12	" + tar	0	
11. K Nm 40/9	brown dyed	75	
12. K Nm 54/15	untreated	75	
13. K Nm 54/15	tarred	10	
14. K Nm 40/15	untreated	5	
15. K Nm 40/15	tarred	0	
16 K Nm 20/9	brown dyed	25	
17. K Nm 20/9	tarred	5	
18. C Nm 50/15	oil coated	10	old nets
19. C Nm 54/15	chromate-copper	25	
20. C Nm 54/15	ditto + tar	0	

As indicated in Table VII, the wear rate depends on the type of material and proper preservative physico-chemical treatment considerably reduces net wear. So far as the polyamide untreated nets are concerned, a low mesh stability resulted in significant mechanical wear despite their high initial strength. The treated polyamide nets are highly resistant to abrasion. Untreated 'Kuralon' should not be used, since it has many disadvantages which can be overcome by proper treatment.

The following general conclusions may be drawn from this part of the experiment:

(a) Driftnets should be made of materials with a relatively high strength and sound mesh stability.

(b) A careful selection of the twine is necessary to obtain proper relation between twine strength and the forces acting on it during the fishing operation.

(c) A proper physico-chemical treatment of the net materials is of great importance as it reduces mechanical wear.

Effect of mesh arrangement

The driftnet known in Poland as the Dutch driftnet is a basic type commonly used in the North Sea. In the main netting the run of the meshes is with the knots in the lengthwise direction of the net, but across the knots for the top and bottom selvedges.

In the opinion of many observer-fishermen, this arrangement was best because of the reduced number of fish falling out during hauling, and also because the main forces during hauling, act "with the knots". It seemed

advisable to try various arrangements and this was done as indicated in Table VIII.

Table VIII Mesh arrangements of the driftnets used

N = normal; S = simplified; St. Steelon, K.= Kuralon, C = Cotton

Type & twine size of main netting	Twine size of selvedges	Material	Treatment	%	No. of nets
1.N simplified 265 d/9	265 d/9	St.	tarred	33.0	5
2.N simplified 265 d/12	265 d/12	St.	none	-	3
3.N simplified 265 d/12	265 d/12	St.	tarred	31.3	5
4.N unstrengthened Nm 20/9	None	K	dyed	-	5
5.N unstrengthened Nm 20/9	None	K	tarred	20.6	18
6.N unstrengthened Nm 40/15	None	K	none	-	2
7.N unstrengthened Nm 40/15	None	K	tarred	34.25	2
8.S inverted Nm 20/9	Nm 20/12	K	dyed	-	5
9.S inverted Nm 20/9	Nm 20/12	K	tarred	34.3	20
10.S inverted 265 d/12	265 d/12	St.	tarred	31.3	3
11.N inverted Nm 50/15	Nm 50/18	C	tarred	27.9	10

These gillnets were used simultaneously with normal driftnets.

On the basis of these experiments, a simplified arrangement for thinner materials and a simple unstrengthened arrangement of the netting of greater mechanical strength has been chosen for industrial manufacture.

Estimate of crew work

The amount of crew work differed according to the material used. In general, work increased when polyamide and 'Kuralon' driftnets were used, decreased when oil-coated cotton gillnets were used.

The amount of work was estimated directly and indirectly by measuring the operation time for each type of driftnet, the fatigue rate of the crew and the eventual frequency of shifts during removal of the herring.

In general, the thin untreated polyamide nets, with yarn number Nm 50/9 and Td 265/9 or Nm 34/9 are very tiring, and in fact are rather unsuitable as a commercial fishing gear. 'Kuralon' is better to handle than polyamide, especially when coated with a tar substance.

Based on the experiments, 'Kuralon' twines of Nm 34/12 have been selected for use in commercial fisheries.

Commercial experiments

Commercial experiments were planned and carried out in 1961 and 1962. They consisted in equipping a commercial vessel with an experimental set composed of either 'Kuralon' or cotton and 'Kuralon' driftnets. The crew and the skipper fished this set according to typical commercial principles and prepared a report after each voyage.

During the two years mentioned, 20 commercial voyages were made, during which it was concluded that the fishing effectiveness of the 'Kuralon' driftnets does not differ from that of standard cotton gillnets. The wear of 'Kuralon' nets was, on average, 10 times smaller compared with cotton. This may not hold true in future experiments as some of the cotton nets had been used whereas all the 'Kuralon' nets were new. The skipper, as well as the crew, indicated that the amount of work for the operation of the 'Kuralon' nets is similar to that required for the operation of cotton gillnets.

On these experiments, Polish fishermen have gradually started to use 'Kuralon' nets made of Nm 34/12, and treated with petro'eum tar (coating of 30 per cent.).

By the end of 1962, more than 2,000 'Kuralon' driftnets were in use compared to 8,000 cotton driftnets. From the wear data for the year 1962, it transpires that the replacement for the 'Kuralon' driftnets (losses at sea and normal wear) averages nine per cent per year compared to approximately 50 per cent for cotton nets.

Our further work will deal with the elaboration of driftnets made entirely of synthetic fibres.

General conclusions

1. Of the analysed materials, polyamides as well as polyalcohol vinyl ('Kuralon') are suitable as material for herring gillnets.
2. In spite of the many qualities of polyamide (great strength, fishability, gripping quality) 'Kuralon' has better overall utility for herring driftnets and costs less.
3. The special treatment required for the polyamides and the necessity of a greater thickness of the twines for handling limit to some extent their use as herring gillnets.
4. The simpler treatment of the 'Kuralon' and good fishing results indicated that this material is better suited for herring driftnets.
5. The number of fish damaged during shaking depends on the quality of the material, the thickness of the twine and the degree of stiffening.
6. The mesh arrangement in a gillnet has no direct influence on the fishing efficiency of the net. Based on observations, however, the best arrangement seems to be that normally used in the North Sea herring driftnet fisheries.
7. The commercial fishing experiments have confirmed the high qualities of the 'Kuralon' twines for driftnets.
8. On the basis of two years of experiments, 'Kuralon' nets (with treated sisal lines) need only one-fifth as much replacement as cotton driftnets. Into consideration there was taken Polish type of fishing operations, in which vessels catch with driftnets through a part of the year and with trawls through another one.

Discussion: New net materials

Mr. Pierre Lusyne (FAO) Rapporteur: At the first World Fishing Gear Congress in 1957 the characteristics and use of several synthetic fibre materials were much discussed because of their newness. Since then some have practically disappeared while others have firmly established themselves, such as nylon, polyester, polyethylene, polyvinyl alcohol and its various combinations. To choose appropriate material

for a specific fishing gear is not simple and among the synthetics now used in fishing, many factors such as wet knot strength, elasticity, abrasion resistance, etc., must be carefully considered.

A new material is polypropylene which belongs to the polyolefin group and has many of the characteristics of polyethylene which was brand new six years ago, but is now well established as trawl twine material. The characteristics of polypropylene are fully described in Dr. Klust's paper after testing some 40 samples. Polypropylene has the lowest density of all materials used for twine manufacture and has the same strength in wet or dry condition. Based on breaking length it has the same strength as nylon, but will, for the same strength, be thicker due to its low density. Klust also showed that in the wet knotted condition polypropylene and nylon of comparable R tex value have the same breaking strength.

He found a remarkable difference in extensibility; polypropylene stretched much less than nylon and the load extension increase was almost linear. This is very different from nylon which has a great extension at low load but with increasing load gives a constantly decreasing percentage of stretch. Polypropylene, on the other hand, has a high creep value when under continued load, so that the permanent elongation is higher than that of polyamide. This is an important factor as it may affect its suitability for net parts where heavy and consistent loads are applied, which then cause undesirable mesh changes.

The paper by Carter and West on the properties of 'Ulstron' one of the first polypropylenes used (at least in the fishing twines), gives much the same figures as Klust in regard to its properties, but refers to other synthetic twines such as polyethylene, polyester, nylon, polyvinyl alcohol and some of the natural fibres and provides a very useful basis for comparison.

Polypropylene softens at 160°-170° C and should therefore not be submitted to high temperatures during stretching and heat-setting, although 100° C (and therefore boiling water) is quite safe.

The fact that some papers vary in details of the catching efficiency of polypropylene compared to other twines is no doubt due to the need for more experience and further adaption of gears. Klust quotes Carrothers in giving polypropylene a slightly higher catch efficiency than nylon both in gillnets and bottom trawls. Carter and West's results are approximately the same. The Japanese, however, found polypropylene gillnets to be rather bulky for handling and their catching efficiency slightly lower than that of nylon. Polyethylene, in the meantime, has been fully accepted and is now extensively used especially as a trawl net material.

According to the Japan Chemical Fibres Association 78,000 tons of synthetic nets and ropes are now in use in Japan compared to about 9,000 tons of natural fibre material, which shows their highly modern outlook. It is, however, remarkable that while the conversion to synthetics is 90 per cent for netting, about 80 per cent of the ropes used are still of natural fibres.

Much headway has been made since the last Gear Congress in the construction of braided twines. On this point Bombeke reports tests which showed that the drag of braided nylon twines is lower than that of twisted twines; both showed one-half less drag than cotton at a speed of three knots. The actual testing was done in an air tunnel and the results recalculated to give the drag in water.

Mohr reports on experiments carried out in Germany to use plastic material for creels and pots. While first efforts were not quite satisfactory, plastic traps were later made which caught as many eels as the usual rattan traps. Such plastic traps, though initially more expensive, had a much longer useful life.

Dr. Katsuji Honda (Japan): As a result of continued effort in recent years, the strength and quality of the twine made from polypropylene had been considerably improved as these figures show:

	Multifilament yarn	*Spun yarn*	*Monofilament yarn*
1961	5·5—6·0 g/d	3·7—3·8 g/d	5·5—6·5 g/d
1962	6·0—7·0 „	4·0—4·5 „	5·5—6·5 „
1963	7·5—8·0 „	5·5—6·5 „	6·5—7·0 „

In strength it has been made even stronger than nylon and in weathering there would be no further problem. As with other fibre materials all kinds of industrial uses can be expected of this material but experimentation was still required regarding its use as rope. It had been found that in strength it was stronger than, or almost as strong as, polyvinyl alcohol but not yet as strong as nylon. There are various advantages, however, because of its light specific gravity, its flexibility and abrasion resistance; and it is expected to be adequate for use as rope. For further improvement they were studying prices and economic conditions and also the question of durability.

Mr. V. Valdez (Peru): There are now 1,200 boats operating in the Peruvian anchovetta industry. The great richness of plankton in that area caused cotton nets to rot quickly but synthetic nets do not rot and all the nets now used are of nylon.

Mr. D. Roberts (UK): In trawling some years back, we were not too sure about synthetics but I am now 100 per cent convinced and we never want to buy anything but synthetics for trawling in future.

Mr. J. Norman (UK): As a District Inspector of Fisheries my duties necessarily include enforcement of regulations. With the introduction of synthetics it has become difficult to distinguish between the four main groups and I would like to know if there are any simplified methods of identifying them.

Dr. von Brandt: That problem has been much discussed. There are many fibre producers here. Can anyone give an answer for the main types of synthetic fibre especially those used in trawls?

Mr. Eric Kwei (Ghana): In using synthetic nets we found that in our tropical waters fish that were gilled died quickly and when they were taken out had already begun to putrefy. What is the possible remedy?

Mr. B. W. Crewdson (UK): The question about mesh sizes as interpreted by Government Authorities is a very vexatious one. Dealing with synthetics is very different from natural fibres. The material itself might not shrink but when put into a net form there is very pronounced shrinkage. It is our trade custom to measure mesh sizes between net knot centres, whereas government authorities measure the mesh opening (lumen). Braiding nets is not an exact science. If done by hand there is variation. If done by machinery it is a matter of relation. If you are $\frac{1}{8}$th of an inch below you are in the red with the Ministry and if above, with the Skipper. We are in a most difficult position. There should be some standardisation which, at the moment, there is not. In America, nets are measured before use and they are sealed, but here the mesh is supposed to be measured after use and when wet. That is the question of mesh size in relation to synthetics and it is very serious. Can manufacturers tell us what proportion of shrinkage there is in the product they produce?

Dr. von Brandt: This problem we have also discussed on the Permanent Commission. It is very difficult not only for synthetics. Specifications of some nets call for mixtures which differ from time to time. There is no real answer.

Mr. W. Henstead (UK): We can all sympathise with Mr. Crewdson, but yarn manufacturers are entitled to sympathy too. We know this problem and we are doing all we can to combat it. One constructive suggestion we made was that there should be one regulation for monofilaments, one for staple fibres, and one for multifilament yarn.

Mr. Harper Gow: Can anyone give details of the United States method and say whether it is satisfactory to the net maker and the skipper?

Mr. Lusyne thanked Dr. Honda for clarifying the position in Japan regarding the production and properties of polypropylene. For distinguishing different fibres, various means were known, such, for instance, that burning nylon gave off white smoke and left a residue of hard black quality; other fibres reacted differently, but the real tests were chemical and they could only thus distinguish the different fibres.

There were practical methods which had been published and re-published. We could suggest that FAO include in the Fishing Gear Designs Catalogue some simple methods for testing fibres.

The only practical answer to Mr. Kwei's problem of fish rotting in synthetic gillnets was to haul the nets and clear them more frequently.

To Mr. Crewdson's problem he could see no real answer. Stretch could arise not only from the material but from the knots themselves tightening or giving. There would always be movement in the mesh of knotted nets. He thought the regulations should state clearly whether, and how many meshes should be taken or sampled in different parts of the net to decide whether the average mesh size conformed with the regulations. The nets did change in use and the regulations should recognise that.

Dr. von Brandt: That is also a problem for the Permanent Commission and he thought most delegates of the different countries would discuss the right regulations for checking mesh sizes.

Mr. Kristjonsson (FAO): We should be discussing here mainly the suitability of the different materials for different fishing methods and fishing gear. He suggested that polypropylene might advantageously be used in some purse seines because of its lightness and capacity for floating in the water. This should reduce fouling when making sets in shallow water provided the necessary weights were concentrated in the purse rings instead of using a leadline. He would like to hear other provocative statements about the use of certain types of materials for different fishing needs.

Mr. Valdez (Peru): Our Fishery Institute is considering buying polypropylene in order to test it for purse seines.

Mr. R. K. N. Ocran (Ghana): Our traditional methods were to fish with natural fibres but cotton nets rotted after two months. After the Hamburg Congress and his own experience in Scotland, they tested nets of cotton, 'Kuralon' and nylon. 'Kuralon' was very heavy and sank quickly and tended to get caught on the rocks. With nylon used in shallow water, they had some success, but in deeper water, because the net was light and slow to sink, 75 per cent of the fish in a nine-months trial of seine nets escaped before they could catch them. If they used leadlines the net would sink quickly enough but the net would foul. To solve that problem they were now trying another net from a different maker.

Mr. E. F. Gundry (UK): One of the problems of a netmaker is the multiplicity of synthetic fibres. This is handicapping the commercial success of netmakers. Some settlement should be arrived at as to the ideal materials to be used for different fisheries so that netmakers would not have to carry so much stock in different lines. This would contribute to the economy of the netmaking industry.

Mr. E. Allers Nilssen (Norway) agreed it would be far easier for manufacturers to have only a few synthetic fibres. Synthetics certainly floated more and sank slowly, therefore they had tried to find out the right kind of dressing to keep purse seine nets upright in the water. He did not agree that polypropylene would be of any advantage in purse seining. On the contrary. On the setting of knots and mesh sizes, their experience was that if netmakers used synthetic fibre they could know exactly what the shrinkage was. If a net was really properly knot set there would be very little variation in the mesh size.

Mr. E. A. Schaefers (USA): In experiments of synthetic materials tar has reduced the abrasions on the fish caused by the material. It has also probably reduced the catchability of the nets but they still maintain the durability which is one of the main features of synthetics against cotton fibres.

Mr. Ocran: The difference between fish caught by cotton and nylon is that when the fish struggle the fine twine cuts and the fish deteriorates before it reaches the consumer so the impression in our country is that nylon-caught fish deteriorates more than cotton caught fish.

Mr. C. Crewdson (UK), on the point of dressing synthetics with bitumastics or pitch material, said he had always understood the fibres were impervious to bacterial action. They did not need dressing to give durability. His firm gave bitumastic treatment to synthetic nets merely to give rigidity because those nets were so limp that they tended to foul in handling.

Mr. Schaefers: I have been misunderstood. I was merely trying to point out that the treatment of synthetics with tar was to reduce abrasion on the fish and not to extend the life of the material. I agree completely with Mr. Crewdson.

Mr. Lusyne, in summing up, said that Mr. Gundry's problem of limiting the number of materials could not be easily met. They could not just say that any particular material would make a good net. They had to qualify that by saying it is a good net at certain places at certain times. One fisherman would succeed with it and another would not. Their individuality had to be met. The gear the fisherman used was that which best suited his operation. No agreement would be possible in the way of manufacturers limiting themselves to three or four materials. Furthermore such standardisation would mitigate against progress.

Ropes of Polyethylene Monofilaments

by

C. C. Kloppenburg

J. Reuter

Abstract

Polyethylene monofilaments are manufactured by extrusion, followed by an orientation process. Two factors have a significant effect on the properties of these filaments, i.e., type and quality of the polymer used for production and the degree of stretch applied at the orientation stage. The properties of monofilaments made from three different polyethylene types have been compared with the normally given specifications for these raw materials. The influence of the stretching percentage on the filament properties, has been determined quantitatively. Polyethylene monofilaments with the same diameter, but with different properties, were twisted and stranded into twines and ropes. The mechanical properties of these twines and ropes were compared with the filament properties. The conclusions arrived at were as follows: (1) Melt index and specific gravity are insufficient specifications for characterising polyethylene raw material, suitable for monofilament production. (2) Under comparable circumstances ethylene copolymers give stronger monofilaments than ethylene homopolymers. (3) The monofilaments of highest breaking strength do not give the best net yarns in respect of the knot tenacity in netting. (4) For rope making, highly stretched monofilaments are desirable.

Résumé

La production des monofilaments de polyéthylène s'exécute en deux phases suivies l'une après l'autre: l'extrusion et l'orientation. Deux facteurs importants influencent les propriétés des filaments obtenus: le type et la qualité du polymer destiné à leur production et le degré de l'étirage appliqué lors du procès de l'orientation.

Les propriétés des filaments fabriqués à base de trois types différents de polyéthylène ont été comparées avec les spécifications données régulièrement pour ces matières premières. L'influence de l'étirage sur les propriétés des filaments a été déterminée quantitativement. Des monofilaments d'un même diamètre, mais avec des propriétés différentes ont été retordus et assemblés en câbles et en cordes. Les propriétés mécaniques de ces câbles et de ces cordes ont été comparées avec les propriétés des filaments.

Les auteurs sont arrivés aux conclusions suivantes: (1) l'Indice de fusion (melt index) et la densité sont insuffisants pour caractériser la matière première servant de base à la fabrication de monofilaments. (2) Dans des circonstances comparables, les copolymers d'éthylène produisent des monofilaments plus résistants que les homopolymers d'éthylène. (3) Les monofilaments ayant la plus grande résistance de rupture ne sont pas les meilleurs pour la confection des filets, par rapport à la ténacité au noeud. (4) Pour la fabrication de cordes, il est souhaitable que les monofilaments aient été soumis à un étirage très élevé.

Extracto

Se fabrican los monofilamentos de polietileno por medio de extrusión, seguido por un proceso de estirar. Dos factores tienen un efecto significante sobre las propiedades del producto: la clase y calidad del polimero y el grado de estiramiento aplicado en la fase de orientación. Las caracteristicas de los filamentos hechos de tres tipos diferentes de polietileno han sido comparadas con las especificaciones usuales para esta materia prima. La influencia del estirar sobre las propiedades de los monofilamentos ha sido establecida en cantidades determinadas.

Hilos monofilamento del mismo diametro pero con caracteristica diferentes han sido retorcidos y ensamblados en cables y cordonos. Las propiedades mecánicas de estos cables y cordones han sido comparadas con las propiedades del monofilamento. Se llegó a las conclusiones siguientes: (1) El indice de fusión y la gravedad especifica son insuficientes para caracterizar el polietileno bruto que reúna buenas condiciones para la producción de monofilamentos. (2) En condiciones análogas dan monofilamentos más fuertes los copolimeros que los homopolimeros de etileno. (3) Los monofilamentos de mayor resistencia a la rotura no producen los mejores hilos para redes respecto a la tenacidad de los nudos en los paños. (4) En las fabricación de cuerdas conviene emplear monofilamentos muy estirados.

IT is well known that monofilaments from polyethylene are manufactured by an extrusion technique, followed by an orientation stage. In principle one can distinguish two different processes. The whole operation can be done in a single "in-line" unit or in two separate units, the first devoted to extrusion and the second to orientation. Fig. 1 gives a comparison of these two manufacturing methods. At the top is single-stage production. The polymer is molten in an extruder, forced through a multihole die and quenched in warm water. Directly after that, filaments are stretched up to eight to ten times their original length in boiling water, and then wound up under constant tension. This process can also be done in a discontinuous way, as is shown below. Here, the unstretched filaments are spooled and afterwards stretched in a second operation.

Both methods have advantages and disadvantages in production. The in-line method requires fewer pieces of

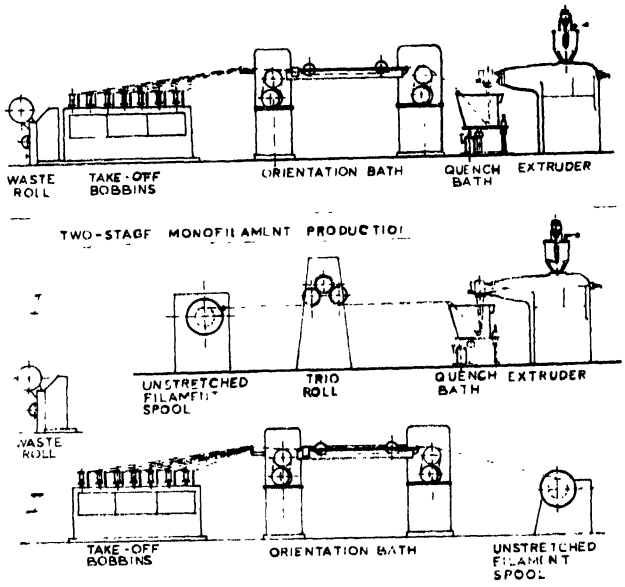

Fig. 1. Single-stage and two-stage monofilament production.

equipment and a simpler attention than the two-unit method. The speed of stretching, however, is in point of principle limited by the extrusion speed. This is a drawback in regard to output. The final selection of the method to be used will depend, among other things, on the number and diameter of the monofilaments. The manufacturing process for polyethylene monofilaments may be relatively simple but needs to be carefully controlled. Different manufacturing conditions can be used and they have more or less influence on the properties of the oriented monofilaments. But this influence is not always clear and some investigations contradict each other. Two factors, however, have a significant effect on the properties of the end product. These are: type and quality of the ethene polymer used for the production and the stretching percentage (draw ratio) applied in the orientation stage. Both factors are discussed.

The raw material

For producing polyethylene monofilaments, mainly three types are considered:

(a) Homopolymer of ethylene, manufactured by Ziegler procedure.

(b) Product obtained by copolymerising ethylene and 1-butene by Phillips process.

(c) The newer commercial ethylene copolymer, obtained by Ziegler process.

These materials are only specified by melt index and specific gravity and sometimes by viscosity data.

For filament production, the types with specific gravity = 0·95 and melt index 0·1 0·3 are recommended. It turned out, however, that these two or three polymer specifications are insufficient for characterising polyethylene material suitable for filament production. In other words, the suitability of an ethylene homo- or copolymer for making monofilaments is not guaranteed when the specific gravity and melt index are within the above-mentioned limits. This does not only relate to the economy of the process but also to the mechanical properties of the obtained filaments (Table I).

From eight different ethylene homopolymer batches, all produced according to the Ziegler process, were determined: density, melt index and intrinsic viscosity. Afterwards, output samples were taken for manufacturing monofilaments in exactly the same way, using a special investigation equipment, and applying a draw ratio of 8:1. The final diameter of the filaments amounted to 0·38 mm (0·0150 in), corresponding with tex 108 (tex = weight in grams of 1000 m of monofilament). Table I indicates the average values of some typical properties of the obtained monofilaments, namely the tenacity determined with and without an "overhand knot", and the elongation at break. These determinations were carried out with a Scott IP4 inclined plane tester. Drawing time: 13 sec. The tenacities are expressed in grams per tex. Dividing these figures by 9, gives tenacity expressed in grams per denier.

Table I. Ziegler-type polyethylene Homopolymer

Batch or Lot number	Raw materials: Determined specifications			Monofilaments: Mechanical properties		
	Density	Melt index	Intrinsic viscosity	Tenacity (g/tex) normal	Tenacity (g/tex) overhand knot	Elongation
1	0.947	0.16	2.16	49.3	37.3	19 %
2	0.950	0.31	1.72	46.0	33.2	19 %
3	0.949	0.29	1.64	40.3	32.3	18 %
4	0.947	0.30	1.73	40.4	31.5	21 %
5	0.947	0.28	1.72	44.3	32.1	17 %
6	0.950	0.20	2.16	48.3	38.0	22 %
7	0.949	0.17	2.16	44.7	34.7	19 %
8	0.947	0.23	1.90	48.0	32.5	18 %
Draw ratio = 8 : 1 Diameter monofilaments = 0.38 mm (0.0150 in.) Tex monofilaments = 108 g/km.				45.2	34.0	19.1%

From these data the conclusion is well founded that, within the investigated range, there is no correlation between density, melt index and intrinsic viscosity on the one side and tenacity or breaking elongation on the other. Starting with the same type of raw material, there are remarkable differences in filament properties depending on the polymer batch that has been used. It is interesting to compare these results with the figures obtained by experimenting, in exactly the same way, with ethylene copolymers produced according to either the Phillips or the Ziegler process (Table II).

Table II. Monofilaments from ethylene copolymers
Draw ratio = 8 : 1. Monofilament diameter = 0.38 mm (0.0150 in.)

Batch or Lot number	Raw materials: Determined specifications			Monofilaments: Mechanical properties		
	Density	Melt index	Intrinsic viscosity	Tenacity (g/tex) normal	Tenacity (g/tex) overhand knot	Elongation
Phillips copolymer						
11	0.950	0.28	1.80	51.0	37.0	20 %
12	0.951	0.16	2.12	58.8	36.9	20 %
13	0.949	0.18	2.09	56.1	34.2	18 %
14	0.950	0.15	2.10	52.0	38.5	19 %
15	0.951	0.22	1.96	52.0	36.5	22 %
16	0.950	0.30	1.70	47.2	33.3	22 %
17	0.948	0.19	1.91	53.3	35.7	20 %
18	0.948	0.21	1.86	47.0	33.5	21 %
				52.2	35.7	20.3%
Ziegler copolymer						
21	0.949	0.26	2.10	57.1	40.6	19 %
22	0.949	0.29	1.86	55.3	38.1	20 %
23	0.948	0.35	1.84	51.3	36.0	23 %
24	0.949	0.26	1.85	49.5	36.5	21 %
25	0.947	0.25	2.12	48.5	38.1	22 %
26	0.948	0.28	1.96	56.8	38.5	17 %
27	0.948	0.34	2.01	57.3	35.5	17 %
28	0.946	0.15	2.13	56.6	38.5	19 %
				54.1	38.0	19.8%

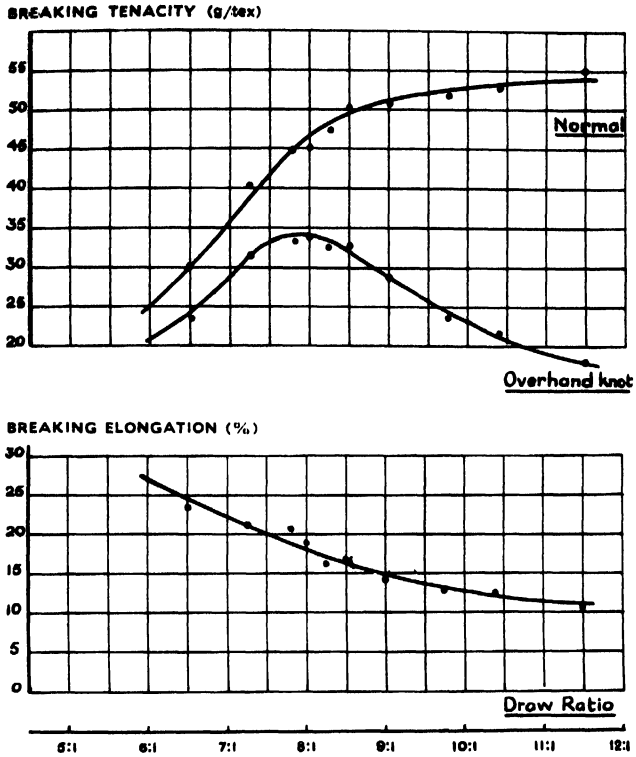

Fig. 2. Monofilaments made from Ziegler-type polyethylene. Homo polymer. (*Filament diameter—0·41 mm*).

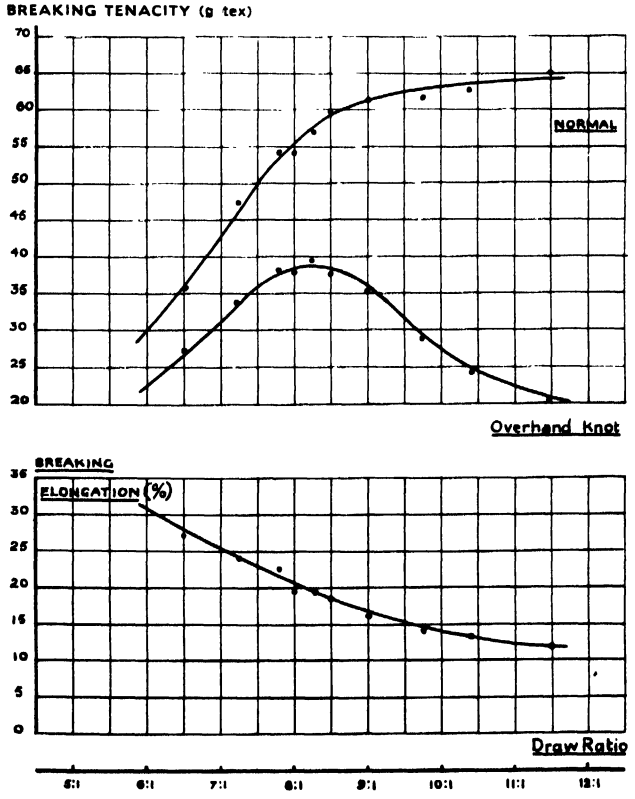

Fig. 3. Monofilaments made from the Ziegler-type polyethylene. Copolymer. (*Filament diameter=0·41 mm*).

Table III. Properties of monofilaments made from the Ziegler type polyethylene. Filament diameter = 0.41 mm (0.0161 in.)

Draw ratio	Breaking tenacity in g/tex		Breaking elongation
	Normal	Overhand knot	
Homopolymer			
6.5 : 1	30.1	23.8	23.6%
7.25: 1	40.4	31.2	21.3%
7.8 : 1	44.7	33.6	20.9%
8 : 1	45.3	33.8	19.0%
8.25: 1	47.5	32.7	16.5%
8.5 : 1	50.3	32.6	16.7%
9 : 1	50.8	28.7	14.5%
9.75: 1	51.9	24.0	13.2%
10.4 : 1	52.8	21.4	12.5%
11.5 : 1	54.6	18.1	11.0%
Copolymer			
6.5 : 1	35.7	26.9	27.3%
7.25: 1	47.5	33.6	24.2%
7.8 : 1	54.3	38.1	22.9%
8 : 1	54.2	37.9	19.7%
8.25: 1	57.0	39.5	19.4%
8.5 : 1	59.5	37.6	18.4%
9 : 1	61.2	35.5	16.3%
9.75: 1	61.8	29.3	14.7%
10.4 : 1	62.7	24.5	13.7%
11.5 : 1	65.0	20.6	12.0%

Here the same picture is seen. The filament tenacities may diverge to 20 per cent depending on the polymer batch that has been used. It is not possible to predict the mechanical properties of the monofilaments from such specifications as: density, melt index and viscosity. These data are apparently insufficient to describe the behaviour of an ethylene polymer for filament production. We can only hope that, in the near future, the suppliers of the raw material will be able to furnish stricter specifications; such as: molecular weight distribution and data concerning unsaturation and branching.

The draw ratio

It is common knowledge that the draw ratio applied in the orientation stage influences the elongation and tenacity of the resulting monofilaments. As a general rule one can say: the higher the stretching percentage, the higher the tenacity and the lower the elongation.

This correlation has been investigated quantitatively by extruding monofilaments with different diameters and stretching the said monofilaments in such a way that the final diameters of the obtained products were the same. The applied draw ratios in this investigation ranged from 6·5:1 to 11·5:1. From the resulting monofils not only the tenacity and elongation were determined,

but also the knot tenacity. Table III gives the results obtained with monofilaments produced from a Ziegler-type homopolymer and a Ziegler-type copolymer, both batches representing an average quality. From these data the two graphs, shown in Figs. 2 and 3, have been made.

Fig. 2 relates to monofilaments made from the Ziegler-type homopolymer. On the x-axis is plotted the applied draw ratio during the production, and on the y-axis the determined tenacity (in grams per tex) and elongation of the obtained filaments. As it turns out, the tenacity increases to a certain level and the elongation decreases when we increase the stretching percentage. This is not the case with the knot tenacity which exhibits a distinct maximum. It is difficult to explain the occurrence of this maximum because a simple "overhand knot", regarded physically, is a rather complex whole in which among other things, a bending modulus, a torsion modulus and a sliding modulus play a part.

Fig. 3 relates to monofilaments made from the Ziegler-type copolymer. The three curves exhibit the same shape as in Fig. 2 but are all at a higher level. This finds better expression in Fig. 4, where the curves are taken together. The drawn lines indicate the results obtained by investigating the Ziegler copolymer and the dotted lines represent the behaviour of the Ziegler homopolymer. The knot tenacity curves have different maxima, concerning both the draw ratio and the tenacity.

Investigation

The foregoing poses the questions as to what raw material should be used, and what draw ratio applied to get the best products for rope and twine makers. The answer may seem rather simple. From the graphs shown, it is possible to find the circumstances for getting monofils with the highest normal strength. According to general opinion, these monofils will automatically yield the best ropes and net yarns, and are therefore most desirable.

To test this the following investigation was carried out (Fig. 5).

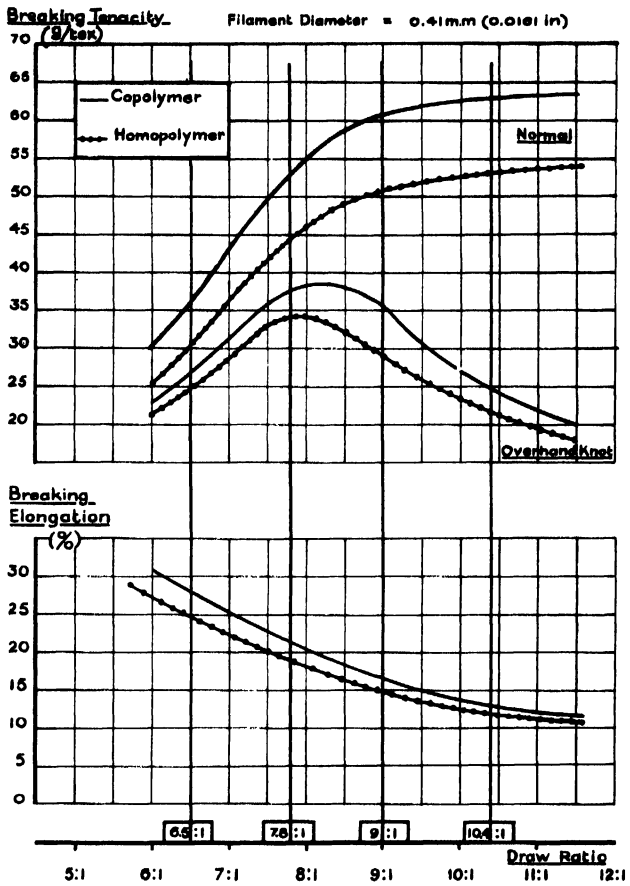

Fig. 4. Monofilaments made from the Ziegler-type polyethylene. Homopolymer compared with copolymer. The draw ratios applied to the investigation as performed are shown by the thick down lines.

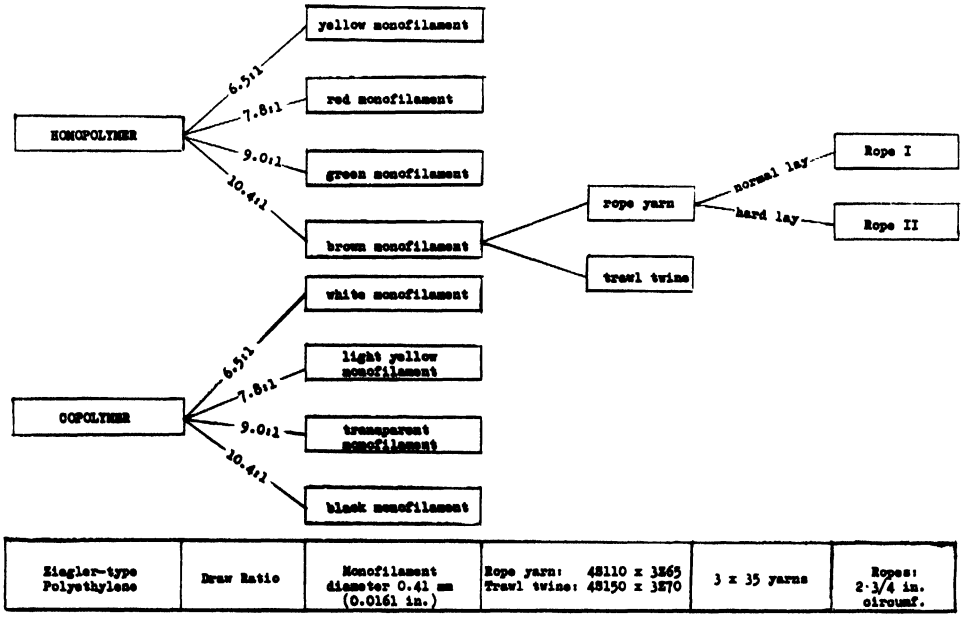

Fig. 5. Programme of investigation.

Starting from both the Ziegler-type homopolymer and the Ziegler-type copolymer, eight different kinds of polyethylene monofils were made using four different draw ratios during the production, viz.: 6·5 : 1; 7·8 : 1; 9 : 1 and 10·4 : 1. The resulting products all had a final diameter of 0·41 mm (0·0161 in). To prevent confusion, the monofilament types were made in different colours. Each filament type was used for making both rope yarn, with the construction 4 S 110 × 3 Z 65, and trawl twine with the construction 4 S 150 × 3 Z 70. From 3 × 35 rope yarns, two types of rope were manufactured: rope I with a normal lay, and rope II with a hard lay. The runnage of the resulting ropes was about 4·5 m/kg, corresponding with a circumference of 70 mm ($2\frac{3}{4}$ in).

Table IV. Mechanical properties of polyethylene monofilaments; diameter 0.41 mm (0.0161 in) (average values of 20 determinations).

	Draw ratio	Colour	Tex	Breaking strength kg.	Breaking strength g/tex	Elongation at break	Knot breaking strength kg	Knot breaking strength g/tex
Ziegler type homopolymer	6.5 : 1	yellow 700	121.9	3.67	30.1	[illegible]	2.91	23.9
	7.8 : 1	red 600	126.9	[illegible]	44.7	20.9	4.26	33.6
	9.0 : 1	green 500	126.7	6.45	50.9	11.5	5.64	28.7
	10.4 : 1	brown 400	128.9	6.80	52.8	12.5	2.76	21.4
Ziegler type copolymer	6.5 : 1	white 800	128.5	4.58	35.7	27.5	3.45	26.9
	7.8 : 1	light yellow 100	125.5	6.81	54.3	22.9	4.78	38.1
	9.0 : 1	transparent.200	126.9	7.76	61.2	16.5	4.50	35.5
	10.4 : 1	black 300	125.0	7.84	62.7	14.0	3.08	24.9

Filament properties

Table IV surveys the mechanical properties of the filament types used.

Not only were the elongation and breaking strength determined, but also the "cold flow" under a permanent load of 12 g/tex.

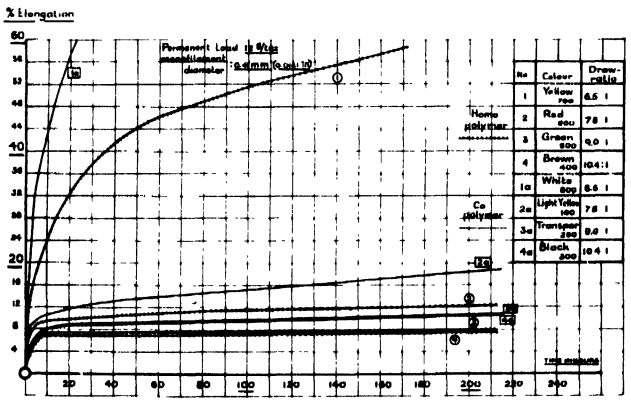

Fig. 6. Cold flow of polyethylene monofilaments. Permanent load: 12 g/tex, monofilament diameter: 0·41 mm (0·0161). The per cent elongation is shown in relation to the time in hours.

Fig. 6 shows remarkable differences among the investigated monofilaments. The lower the stretching percentage during production, the higher the fibre creep afterwards. One can realise that the two monofilament types 1 and 1a, which have a creep behaviour as is shown, having been stretched to only 550%, cannot be used for practical purposes. Further, it should be noted that the copolymers 1a, 2a, 3a and 4a show more fibre creep than the corresponding homopolymers 1, 2, 3 and 4.

Trawl twines

To judge net yarns, the main requirement should be the ability to give a strong net. As the examination of net strength is not so simple, the different net yarns were compared on the basis of their dry "knot strength", using a not too tightly drawn "overhand knot".

The necessary yarns were all manufactured in the same way and on the same machine. To determine breaking strength, use was made of a horizontal apparatus of the pendulum type, constructed so that only the maximum load could be determined. The measuring accuracy amounted to 1 lb and the drawing speed to 80 cm (31·5 in) per min. To test the yarn, it was wound round smooth rollers with a circumference of 19 cm (7·5 in). The distance between the rollers amounted to 50 cm (19·5 in). The yarn always broke either between or below the rollers but never on the rollers. Table V gives the results found by testing the above-mentioned eight different trawl twines.

Table V. Mechanical properties of polyethylene trawl twines (made from 3 x 4 monofilaments). Runnage in m/kg.

Colours	Tex	Runnage	Breaking strength kg	Breaking strength g/tex	Knot breaking strength kg	Knot breaking strength g/tex
yellow 700	1590	628	36.0	22.6	26.0	16.4
red 600	1650	606	54.0	32.7	32.6	19.7
green 500	1710	585	61.2	35.7	28.2	16.5
brown 400	1690	593	62.7	37.1	22.3	13.2
white 800	1630	613	39.0	23.9	30.3	18.6
light yellow 100	1680	594	61.7	36.7	34.1.	20.3
transp-arent 200	1700	587	66.0	38.7	32.3	18.9
black 300	1660	602	68.7	41.3	26.1	15.7

These values are an average of 20 determinations. The only reasonable way to correlate these figures with the monofilament data, is on the basis of the breaking length.

From Table VI it appears that the higher the breaking length of the monofilaments, the higher the breaking length of the net yarns, as would be expected. For the netmaker, however, it is far more important to compare the breaking length of the monofilaments with the so-called knot breaking length of the trawl twines. If this thought is followed, it is found that the strongest monofils do not give the best net yarns. There exists a maximum

in the knot strength of the net yarns, depending on the draw ratio applied during the production of the monofilaments.

Table VI. Breaking lengths. (Trawl twines compared with monofilaments)

	Colour	Draw ratio during the production of monofils	Mono-filaments	Trawl twines	Trawl twines with over-hand knot
Ziegler type homopolymer	yellow 700	6.5 : 1	30.1	22.6	16.4
	red 600	7.8 : 1	44.7	32.7	19.7
	green 500	9.0 : 1	50.9	35.7	16.5
	brown 400	10.4 : 1	52.8	37.1	13.2
Ziegler type copolymer	white 800	6.5 : 1	35.7	23.9	18.6
	light yellow 100	7.8 : 1	54.3	36.7	20.3
	trans-parent 200	9.0 : 1	61.2	38.7	18.9
	black 300	10.4 : 1	62.7	41.3	15.7

Ropes

The samples for the following investigation were made as follows: from each of the eight monofilament types, rope yarns were manufactured with the construction: 4 S 110 × 3 Z 65. This work was carried out on one machine and the resulting rope yarns were tested in the same way as described for the net yarns. The strands were all made from 35 rope yarns and manufactured under the same circumstances. From these strands two types of $2\frac{3}{4}$-in ropes were produced, one with a normal lay and one with a somewhat harder lay.

The testing of the ropes was performed by means of a hydraulic breaking strength machine fitted with grips. The distance between grips was 50 cm (19·7 in), and the rate of movement of the straining head 12·5 cm (4·9 in) per min. From the 32 determinations, only three breakings occurred in the grips. In these cases, however, no different values were obtained. Elongation was also measured under different loads. This was done by marking a distance of about 20 cm (7·9 in) on the rope, and measuring the increase of this length under increasing load. In this manner, load-elongation curves of these polyethylene ropes could be determined.

Fig. 7 shows four characteristic load-elongation curves obtained by testing ropes made from homopolymer monofilaments. The two lower curves show a normal behaviour: increasing elongation with increasing load. The two upper curves, however, exhibit a rather strange behaviour. Here the load increases till a maximum value is attained (by which the rope does not break) and then decreases with increasing elongation. These two curves are found by testing the yellow and red ropes. From the preceding graphs it will be remembered that the yellow and red monofilaments got the lowest stretch during production and, moreover, showed a high creep when

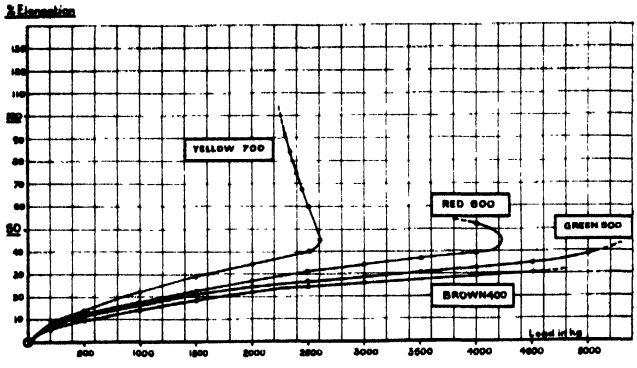

Fig. 7. Ropes made from ethylene homopolymer (normal lay). The per cent elongation is shown in relation to the load in kg. The draw ratio of yellow was 6·5:1, red 7·8:1, green 9:1, and brown 10·4:1

exposed to a permanent load for several hours. The load-elongation curves of the ethylene copolymer ropes exhibit an analogous behaviour, as is shown in Fig. 8.

The conclusion of these experiments is obvious. To avoid undesired creep in the rodes, the monofilament producer has to take care that the stretching percentage in the orientation stage is not too low. The cold flow of monofilaments, when exposed to permanent load, gives already some indication of the rope creep to be expected.

Table VII gives a survey of the data that have been determined by testing the four rope types made from ethylene homopolymer. Each rope has been tested in duplicate and the data show little or no differences. The rope figures can be compared with the yarn properties, indicated at the left side of the table. From the foregoing it is clear that the maximum load does not always correspond with the breaking load. Further, it can be stated that the higher the breaking length of the yarn, the higher the breaking length of the corresponding rope. The hard-laid ropes show a somewhat lower breaking load than the normal laid ones.

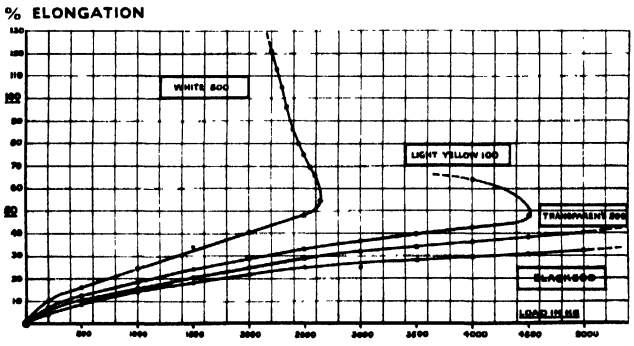

Fig. 8. Ropes made from ethylene copolymer (normal lay). The per cent elongation is shown in relation to the load in kg. The draw ratio of white was 6·5:1, light yellow 7·8:1, transparent 9:1, black 10·4:1.

Table VIII gives the data found by testing ropes made from ethylene copolymer. The tendency is the same as in Table VII, but the figures are on a higher level.

Fig. 9 shows that a linear correlation exists between the breaking length of the rope yarn and the breaking length of the rope.

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Table VII Ropes made from ethylene Homopolymer. N = normal lay, H = hard lay

	Rope yarns made from 3 x 4 monofilaments				Ropes made from 3 x 35 yarns								
Colour	g/m	runnage m/kg	breaking load in kg	breaking length	lay	g/m	number of lays per m	circumference in mm	breaking load in kg	max. load in kg	breaking length	theoretical breaking load in kg	rope yield
Yellow	1,51	662	38,2	25,3	N	204	16,7	67	2125	2600	12,8	4010	65 %
					N	204	16,7	68	2125	2600	12,8		65 %
					H	212	18,5	68	2025	2550	12,0		64 %
					H	210	18,5	68	2025	2550	12,1		64 %
Red	1,51	663	58,4	38,7	N	210	16,3	69	3325	4225	20,1	6130	69 %
					N	214	16,7	70	3325	4225	19,7		69 %
					H	220	18,4	69	3325	4125	18,8		67 %
					H	218	18,4	68	3200	4125	18,9		67 %
Green	1,66	604	68,8	41,5	N	224	15,9	70	5025	5050	22,5	7220	70 %
					N	224	16,3	70	5025	5050	22,5		70 %
					H	234	18,5	70	4850	4925	21,1		68 %
					H	234	18,0	71	4925	4950	21,2		69 %
Brown	1,63	612	68,5	42,3	N	216	15,9	67	5350	5350	24,8	7190	74 %
					N	216	15,7	68	5350	5350	24,8		74 %
					H	226	17,8	67	5100	5100	22,6		71 %
					H	228	17,7	68	5100	5100	22,4		71 %

Table VIII Ropes made from ethylene Copolymer. N = normal lay, H = hard lay

	Rope yarns made from 3 x 4 monofilaments				Ropes made from 3 x 35 yarns								
Colour	g/m	runnage m/kg	breaking load in kg	breaking length	lay	g/m	number of lays per m	circumference in mm	breaking load in kg	max. load in kg	breaking length	theoretical breaking load in kg	rope yield
White	1,60	624	40,7	25,4	N	218	17,1	70	1850	2650	12,2	4270	62 %
					N	220	17,1	70	1925	2650	12,1		62 %
					H	224	18,8	70	1850	2600	11,6		61 %
					H	224	18,8	70	1850	2600	11,6		61 %
Light yellow	1,64	608	63,3	38,5	N	224	16,9	70	2650	4525	20,2	6650	68 %
					N	226	16,9	70	3125	4525	20,0		68 %
					H	234	18,1	70	3400	4400	18,8		66 %
					H	232	17,9	70	2650	4400	19,0		66 %
Transparent	1,63	612	72,3	44,2	N	218	17,0	70	5525	5550	25,4	7590	73 %
					N	218	16,7	68	5500	5525	25,3		73 %
					H	226	18,0	69	5325	5400	23,9		71 %
					H	226	18,0	67	5325	5400	23,9		71 %
Black	1,63	614	80,7	49,5	N	218	16,0	68	5900	5900	27,1	8470	70 %
					N	218	16,2	69	5900	5900	27,1		70 %
					H	226	17,9	68	5800	5800	25,7		68 %
					H	226	18,0	68	5750	5750	25,4		68 %

Tests on Knotless Raschel Netting

by

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Abstract

Knotless nets are of increasing interest for fishing. They are made by two different methods: the Japanese twisting method and the Raschel knitting method. Knotless nets are said to have certain advantages in comparison with knotted nets. Some of these properties (mesh strength, weight, resistance in water, constancy of meshes, and catching efficiency when used for herring driftnets) have been tested for fine knotless Raschel netting. As the main criterion for the exchangeability of knotted and knotless netting, equal mesh strength in wet condition has been adopted. With knotless Raschel netting made of the same fibre material, the mesh strength, the diameter of the bars and the weight per unit area depend to a great extent on the type of construction of twine (bars) and connections. The Raschel machines allow a wide range of various constructions. On the base of equal mesh strength in wet condition, the types of Raschel netting tested in comparison with knotted netting, were found to have (a) less weight per unit area, (b) bigger diameter of bar, and (c) same towing or current resistance in water. The constancy of the mesh size of Raschel netting is better than that of knotted netting. For herring drifting in the North Sea, the catching efficiency of Raschel netting was found to be equal to that of conventional knotted and treated cotton netting of equal twine (bar) diameter (one mm). (The same was found earlier for knotless netting of the Japanese twisting method.)

Epreuves de filets sans noeuds, type Raschel

Résumé

Pour la pêche, les filets sans noeuds offrent un intérêt croissant. Ils sont fabriqués de deux façons différentes: selon la méthode japonaise de retordage et selon la méthode de tricotage Raschel. Les filets sans noeuds sont supposés avoir certains avantages sur les filets noués traditionnels. Certaines de leurs propriétés (résistance des mailles à la rupture, poids, résistance à l'avance dans l'eau, longueur des mailles et efficacité de capture lorsqu'ils sont employés dans les filets maillants pour la pêche au hareng) ont été éprouvées pour les filets sans noeuds Raschel, en fil fin. Le principal critère de comparaison est la force de rupture des mailles en condition mouillée. Avec les filets sans noeuds Raschel, construits dans un même matériau la force de rupture des mailles, le diamètre du fil entre les connexions et le poids au mètre carré dépendent du type de fabrication de ce fil et des connexions ellesmêmes. Les machines Raschel permettent une grande variété de fabrications. Sur la base d'égales forces de rupture des mailles, en condition mouillée, les types de filets Raschel éprouvés avaient en comparaison avec les filets noués: (a) un moindre poids au mètre carré; (b) un plus grand diamètre de fil; (c) une meme résistance à l'avance dans l'eau. La dimension des mailles est plus stable dans le filet sans noeuds de type Raschel que dans le filet noué. Pour la pêche au hareng dans la Mer du Nord, avec des filets maillants, les filets sans noeuds Raschel ont permis des captures égales à celles effectuées avec des filets noués conventionnels de même dimension de mailles, pour un diamètre de fil de un mm. (La même constatation avait été faite avec les filets sans noeuds de type retordu).

Ensayos con redes Raschel sin nudos

Extracto

Las redes sin nudo despiertan cada vez más interés en la pesca; se hacen de dos manera distintas: la japonesa de la torsión y la Raschel del tejido. Las redes sin nudos tienen ciertas ventajas sobre las anudadas. De las redes Raschel sin nudos se han ensayado algunas propiedades, entre las que están la robustez de la malla, peso, resistencia en el agua, firmeza de las mallas y rendimiento de pesca cuando se emplean en los artes de deriva arenqueros. Como criterio principal de la posibilidad de intercambiar redes con y sin nudos, se ha adoptado la igualdad de robustez de la malla cuando está húmeda. Con las redes Raschel sin nudos hechas de la misma fibra, la robustez de la malla, el diámetro de los hilos entre nudos y el peso por unidad de área dependen mucho de la manera de fabricarlas y de las conexiones. Las máquinas Raschel son capaces de fabricar muchas clases de red. Basándose en la igualdad de la robustez de la malla húmeda, las redes Raschel ensayadas eran, con respecto a las anudadas, (a) menos pesada por unidad de área, (b) de más diámetro entre nudos y (c) de la misma resistencia al remolque o a corriente de agua. Las mallas de las redes Raschel son más constantes que las de las anudadas. En el caso de la pesca a la deriva del arenque en el Mar del Norte, la capacidad de captura de las redes Raschel era igual que la de redes de algodón tratado y anudado normales de hilo del mismo diámetro entre nudos (una mm). El mismo resultado se había obtenido anteriormente para redes sin nudos hechas con hilos torcidos.

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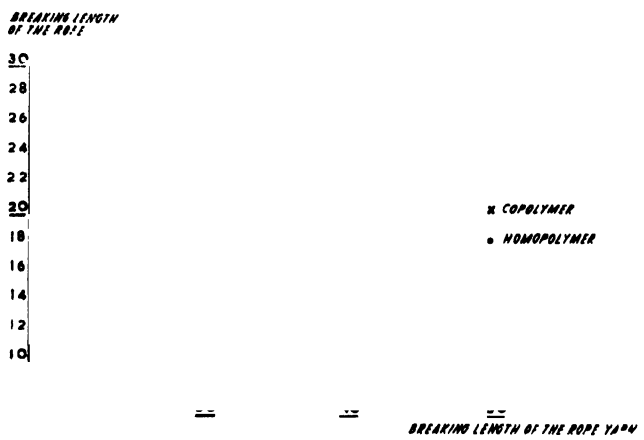

Fig. 9. Breaking length rope versus breaking length rope yarn.

Conclusions

From the investigations come these conclusions:

1. Melt index and specific gravity are insufficient specifications for characterising polyethylene raw material suitable for monofilament production.

2. Under comparable circumstances, ethylene copolymers give stronger monofilaments than ethylene homopolymers.

3. The knot tenacity of monofilaments shows a maximum as function of the draw ratio.

4. The strongest monofilaments do not give the best net-yarns regarding the knot tenacity.

5. For rope making, highly stretched monofilaments are desirable.

Acknowledgments

The monofilaments were manufactured and tested by Nyma Rayon Works (Kunstzijdespinnerij NYMA N.V.), Nijmegen, Netherlands.

The trawl twines and ropes were made by Esbjerg Tovvaerksfabrik A/S, Esbjerg, Denmark, and tested by "Nederlandsche Visserij-Proefstation", Utrecht, Netherlands.

AT present knotted netting is still the main material for fishing nets, including modern fishing gear. Knotted netting is made by hand braiding or by semi- or fully automatic machines. The weaver's knot and the reef knot (especially in Asia) are the main knot types used in netmaking. Double knots developed from these two basic types are also used (v. Brandt 1957).

Recently so-called knotless netting is becoming increasingly important. This interest stems from reports that knotless netting is cheaper than knotted netting and has certain technical advantages. This development makes it necessary to establish testing methods for determining the qualities of knotless netting which are important for fishing purposes and to establish rules for substituting knotless for knotted netting in fishing gear.

Manufacturing techniques

Knotless nets have been well known for a long time. Loosely woven fabric as used, for example for Japanese minnow nets, can also be regarded as knotless netting. Such small meshed material, which cannot be manufactured by knotting, will retain its importance in Asia for catching small fish.

Introduction of chemical fibres for fishing brought the idea of welding or glueing synthetic fibres together to form netting. Stamping or moulding finished net sheets has been tried. Such techniques so far have not produced satisfactory fishing nets.

In 1922, knotless netting made by a twisting technique, was introduced in the Japanese fishery. (Nippon Seimo 1959.) This type of knotless netting is made of twines consisting of only two yarns (Fig. 1a). The connection of the twines to form meshes is made by interlacing the yarns of two twines, once or several times. According to the construction of the joining points, the twines run diagonally through the netting or in a zig-zag line. If the interlacing of the twines at the joining points is done several times, the shape of the mesh may be changed from rhombic into hexagonal. This Japanese twisting technique stimulated efforts elsewhere to develop production techniques for new types of knotless netting.

As a result of these efforts, another type of knotless netting was introduced into fisheries around 1951. The manufacture of this type is based on the Raschel technique, well known in curtain-making for at least 100 years (Fig. 1b). This development has been especially promoted in the U.S.A., Belgium, Italy and Germany. The Raschel technique of knitting is done by special machines (Reichel 1960).

The bars of the meshes are built up by one or two knitted strands and one to three additional woofs for strengthening (Fig. 2). For each strand two guide bars are needed. Usually knitting machines with six to eight guide bars are used for fish netting.

The Raschel machine not only makes the connections to form meshes but also knits the mesh bars. Therefore the Raschel machine produces per unit time, not a certain number of connections but a certain area of netting. The size of this area is not influenced by the mesh size, i.e., with the same type of material the production of a certain mesh size needs double the time needed for producing a mesh of half that size. Thus Raschel machines operate quite differently from knotting machines. The knotting machines work with finished twines and produce only the knots. Per unit time they produce a certain number of knot-rows on which the

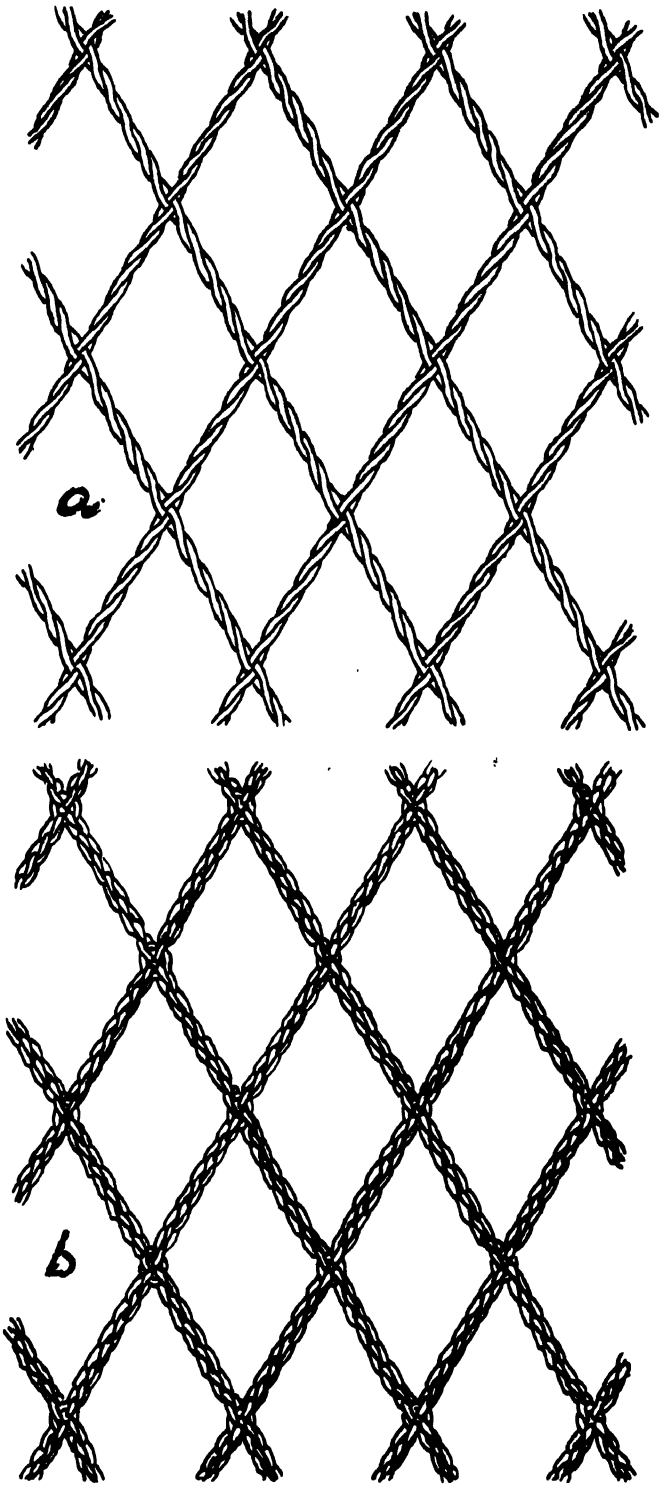

Fig. 1. The two main types of knotless netting used in fishery. (a) Japanese twisted type. (b) Raschel type.

mesh strength can be produced, depending on the type of construction. In all cases tested here, the mesh strength of Raschel netting is higher than that of the knotted netting made of the same fibre material. But it must not be forgotten that the construction of the twine (bar) in the Raschel netting is completely different (Fig. 4) and that the twine number given for the Raschel bar is therefore not directly comparable with the conventional twine number.

Weight of knotless Raschel netting

In general the trade with netting is based on the weight of a net sheet 100 m long and 100 meshes wide, absolutely dry, plus an official moisture content which depends on the kind of fibre. With decreasing mesh size, the weight of a given area of netting increases very quickly because the number of mesh bars and knots is increasing. In the heavy codends of bottom trawls made of manila, double braided, with a mesh size of 70 mm stretched, the weight of the knots can be more than 60 per cent of the total weight. The share of the weight of the knots increases with decreasing mesh size and increasing twine diameter.

Since for the present tests only small samples were available, the tables commonly used by netmakers for calculating the weight of net sheets could not be used, and the net weight had to be newly determined. This was done for pieces of netting of different size but of 32 meshes each made of medium-laid continuous multifilament nylon twines (Fig. 5).

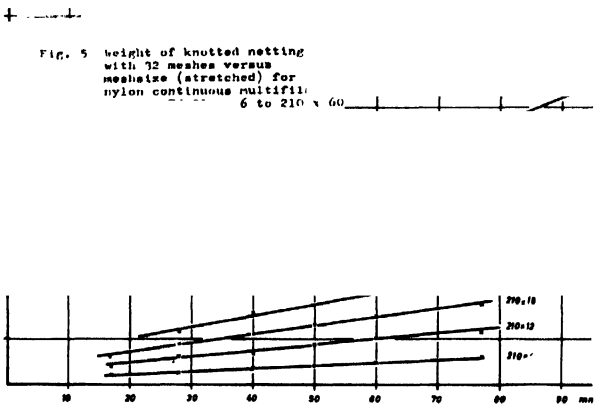

Fig. 5. Weight of knotted netting per unit area versus mesh size (stretched) for nylon continuous multifilament twines, Td 210 × 6 to 210 × 60.

The mesh size (stretched) was determined with a special pressure gauge (1 kg) constructed for fine netting (Florin, 1957).

For the comparison of weights of netting it must be taken into account that knotted netting very often and knotless netting, especially when made of synthetic fibres, are practically always treated during manufacture or later with some bonding agent which adds to the weight. The data in Fig. 5 are for untreated knotted netting and can only be compared with untreated knotless netting.

The weight of the Raschel netting samples in Table I, in comparison with knotted netting of the same mesh strength according to Table II, is given in Table III.

TABLE III

Mesh size stretched (mm)	Raschel netting	Weight (g)	Knotted netting	Weight (g)
19·6	210×11 normal	0·5	210×18	0·8
50·0	210×11 normal	1·1	210×18	1·3
80·0	210×11 normal	1·7	210×18	1·9
19·6	210×11 special	0·5	210×21	0·9
50·0	210×11 special	1·2	210×21	1·6
80·0	210×11 special	1·8	210×21	2·2
19·6	210×11 super	0·7	210×24	1·0
50·0	210×11 super	1·4	210×24	1·8
80·0	210×11 super	1·8	210×24	2·5

According to this small number of samples at equal mesh size and equal mesh strength, of the three constructions tested, Raschel netting is lighter than knotted netting. This means that Raschel netting of the tested types gives more net per unit weight than knotted netting of the same mesh size and mesh strength.

Towing resistance of Raschel netting

The towing or current resistance of netting in water is of high interest for all towed or dragged fishing gear, as well as for gear set in a current, because the resistance and the water pressure wave caused thereby have a bearing on construction and power requirements and may also influence the catching efficiency of the gears. The current of towing resistance depends on mesh size, twine diameter (mesh bars) and size and kind of the joining points of the meshes.

The diameter of normal net twines is relatively easy to measure. Some values for medium laid, continuous multifilament nylon twines are given in Table IV (Klust 1960).

To determine, for comparison, the diameter of the mesh bars in Raschel netting is more difficult. Due to the construction, the cross-section of the bars in Raschel netting is not circular, but more or less rectangular. Since it cannot be predicted which side of the bar will face the waterflow in a fishing gear, the wider side has to be considered.

The following comparison has been made with the same samples of Raschel netting (Table I) versus the same corresponding samples of knotted netting (Table II). As can be seen in Table I, the diameter of the bars in Raschel netting can vary considerably according to the structure, even if the fibre material is the same. Due to the specific structure, the same twine number or count results in a thicker twine or mesh bar in Raschel netting

TABLE IV

Td.	Diameter (mm)	Td.	Diameter (mm)	Td.	Diameter (mm)
210×2	0·28	210×18	0·84	210×36	·30
3	0·32	21	0·92	48	·40
6	0·45	24	1·00	54	·50
9	0·60	27	1·05	60	·57
12	0·67	30	1·10	72	·72
15	0·78	33	1·20		

compared with normal twisted net twine in knotted netting. The reason is that in the knitted bars of Raschel netting the main strands are reversed in direction by knitting and appear in the cross-section several times (See Fig. 2). The comparison of the diameters of the bars of Raschel netting with those of knotted netting of equal mesh strength is given in Table V.

For equal mesh strength the bars of Raschel netting are always thicker. This could be a disadvantage of knotless Raschel netting in comparison with the knotted netting but, as mentioned before, the towing or current resistance of netting in water does not depend on the diameter of the bars alone, but also on the area and shape of the connections.

TABLE V

Raschel netting material structure	Diameter (mm)	Equal to knotted netting material	Diameter (mm)
210×11 normal	1·05	210×18	0·84
210×11 special	1·10	210×21	0·92
210×11 super	1·14	210×24	1·00

The determination of the area of the joining points as a criterion for towing resistance is even more difficult. The joining points can be projected on a plane and the area measured by planimetering (v. Brandt 1958a). This is, however, not enough for a comparison of knotted and knotless connections because the differences in the three-dimensional shape of the joint points is neglected and this will also influence the resistance in water.

The determination of the projected area of netting is therefore considered an insufficient guide in comparing towing or current resistance of netting. For reliable comparative results it has to be measured with samples of complete netting (bars and joining points together) in a towing tank. For the present studies netting samples of 1 m² were tested normal to the direction of tow (N.N. 1960). Since such towing tests are rather expensive, the number of samples tested so far is limited and comprehensive tables for the towing resistance of knotted netting of different materials and different mesh sizes are not available yet.[3]

For the present comparison the same samples (Table I and Table II) have been tested. To keep the number of samples small, this comparison was limited to a mesh size of 50 mm stretched (No. 4, 5 and 6 in Table I and II). The results for a towing speed of 0·6 to 2·0 m/sec (1·2 to 3·8 knots) are shown graphically in Figs. 6 to 8.

Fig.	No.	Material	Mesh size (mm)	Diameter of bar (mm)
5	2a	Raschel, normal	49	1·05
	2b	knotted, 210×18	49	0·84
6	3a	Raschel, special	50	1·10
	3b	knotted, 210×21	50	0·92
7	4a	Raschel, super	50	1·14
	4b	knotted, 210×24	50	1·00

[3] The present tests have been made in the towing tank of Ingenieurschule, Hamburg, by Oberbaurat Bischoff.

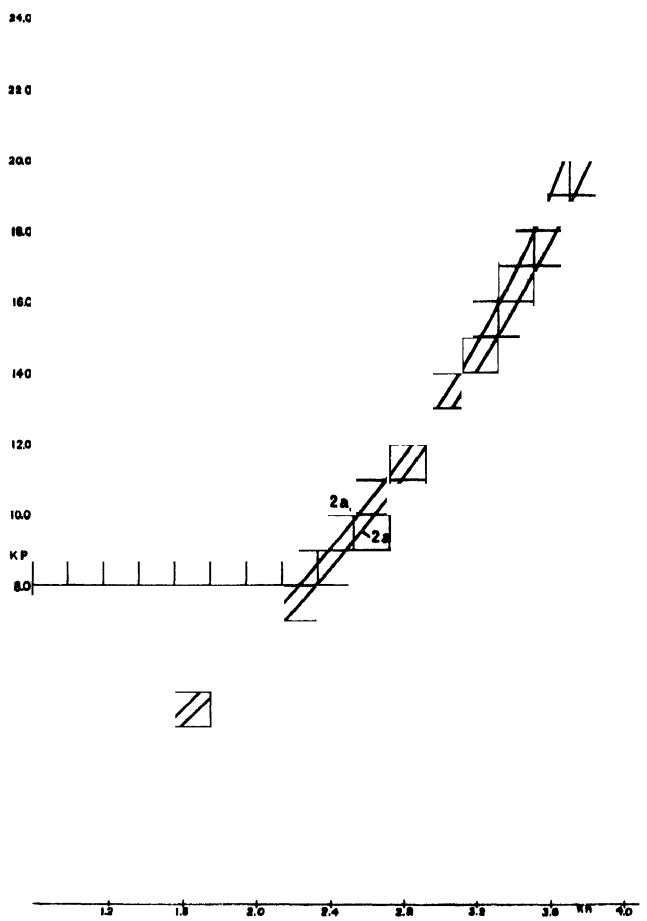

Fig. 6. Towing resistance of samples of 1 m² of netting of equal mesh strength normal to the towing direction. Mesh size 49 mm stretched mesh shape square. 2a. Raschel, normal, 210×11, diameter of bar 1·05 mm. 2b knotted, 210×18, diameter of bar 0·84 mm.

In spite of the thicker bars of the Raschel netting, no difference in the towing resistance could be found in comparison with knotted netting of the same mesh strength. Obviously the higher towing resistance of the thicker mesh bars of the Raschel netting is just compensated by the lower resistance of the joining points. As regards towing resistance, knotless Raschel netting and normal knotted netting are practically equal.

Constancy of mesh size in Raschel netting

Mesh-size measurements for comparison have to be made with mesh measuring gauges applying defined pressure. For fine netting the official pressure gauge of the Lake of Constance can be used (Florin 1957). For heavier netting, e.g., bottom trawls of deep-sea trawlers, a special pressure gauge has been developed for the area of ICES and ICNAF which measures the opening of the meshes only, excluding the knots (Bohl 1961a). For testing the constancy of mesh size, a representative number of meshes in a net sample is measured and the standard deviation is determined. The test may be done with new or used netting according to the purpose of the study.

For the present study, roundfish bottom trawl codends made of 'Perlon' were compared. One was single braided

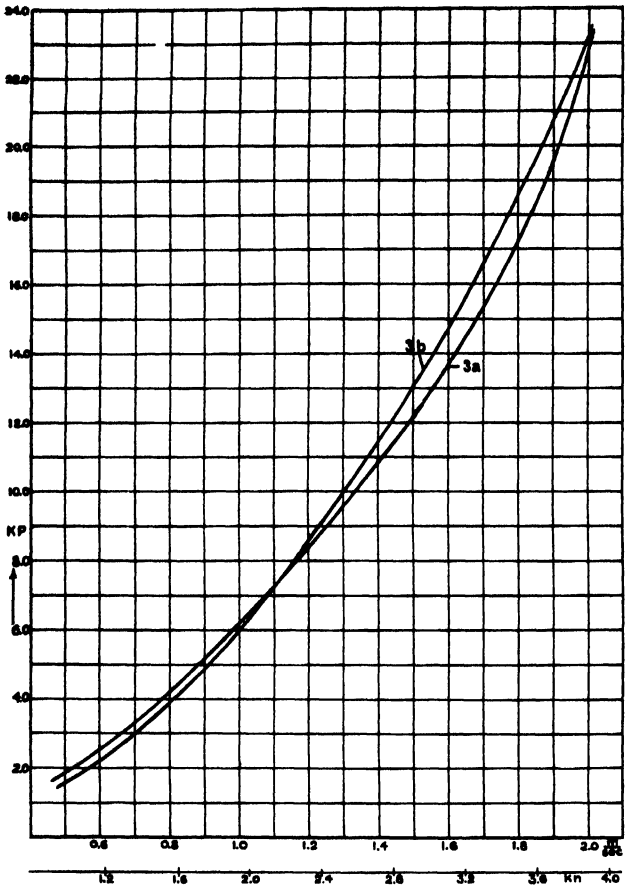

Fig. 7. Towing resistance of samples of 1 m² of netting of equal mesh strength normul to the towing direction. Mesh size 50 mm stretched, mesh shape square. 3a Raschel, special 210 × 11, bar diameter 1·10 mm. 3b knotted, 210 × 21, bar diameter 0·92 mm.

Raschel netting, with short joining points. Two others were of knotted netting. With the knotless codend some heavy redfish catches had been made. The results are given in Table VI (Bohl 1961b).

TABLE VI

Codend type	Number of meshes measured	Mesh size in average	Standard deviation
knotless	360	121·3 ±0·1 mm	1·7
knotted	368	128·8 ±0·2 „	4·2
knotted	232	145·7 ±0·2 „	3·5

The standard deviation for the mesh size is much less in the knotless Raschel netting than in knotted netting. Of course, the type of the Raschel connections will influence the constancy of the mesh size, and other connection types may give different results.

Comparative catching efficiency of knotted and knotless herring driftnets

As mentioned, the mesh strength is not always the only criterion for the exchangeability of knotted and knotless netting. In driftnets used for herring fishing in the North Sea the bars of the meshes must have a certain diameter (1 mm). A smaller diameter would damage the gilled fish. Conventional cotton gillnets (knotted), preserved against rotting and stiffened as used in German herring drifting, have been compared with knotless Raschel netting, normal construction (Fig. 4a), 'Perlon' 420 × 3, also treated to give similar physical properties (Table VII).

TABLE VII

	Cotton knotted	'Perlon' knotless
Mesh size (bar)	25·3 mm	24·9 mm
Mesh strength:		
dry	6·0 kg	15·5 kg
wet	6·3 kg	14·2 kg
Bar, diameter	1·0 mm	1·0 mm
Weight	2·05 g	1·05 g

Table VII shows the mesh strength of the Raschel nets was much higher than that of the knotted cotton nets. This could not be avoided, because it was necessary to have the diameter of the mesh bars no smaller than 1 mm. The knotless nets were much lighter but this, to a certain extent, was due to the difference in treatment with bonding and protecting agents.

For this experiment, 11 knotless driftnets were inserted between conventional knotted cotton nets in the same fleet of driftnets. For comparative tests of the catching efficiency of certain single driftnets operated

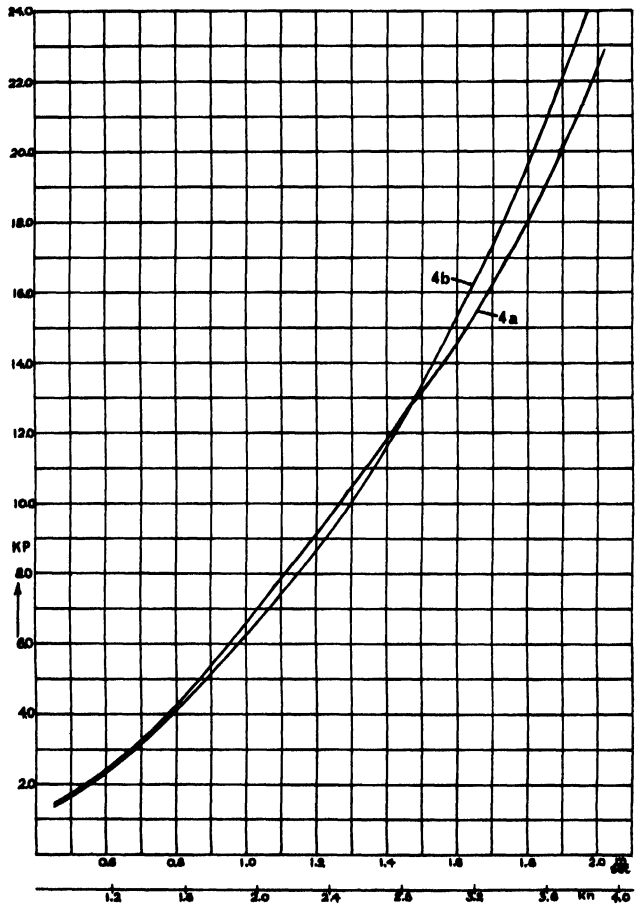

Fig. 8. Towing resistance of samples of 1m² of netting of equal mesh strength normal to the towing direction. Mesh size 50 mm stretched, mesh shape square. 4a Raschel, super 210 × 11, bar diameter 1·14 mm, 4b knotted, 210 × 24, bar diameter 1·00 mm.

with a great number of conventional driftnets in the same fleet, the catch in all the nets of the whole fleet has to be considered. If a small school hits a fleet of driftnets it will fill the nets in the section corresponding to its size and leave the rest empty. The resulting uneven distribution of catch over a long fleet of nets is quite normal in herring drifting. In order to avoid that the nets under test do not meet statistically inadequate conditions in a limited number of observations, a special observation method has been developed (v. Brandt 1955). The number of fishes gilled in each single driftnet is counted or estimated, and represented graphically. In this way it can be seen how the catches vary from net to net in a fleet. Where the efficiency of nets under tests differs from the conventional nets, the more or less smooth curve of the diagram will be interrupted.

This method was used earlier to compare catching efficiency of knotless 'Manryo'-nets (Japanese twisting technique) with conventional knotted cotton driftnets for herring in the North Sea. No difference could be found (v. Brandt, 1958b).

For the present comparison of conventional knotted cotton nets with knotless Raschel nets (Table VII) the results of eight sets have been evaluated.[4] Different quantities of herring were caught per set (2·5 to 10·5 tons). The catching efficiency of the Raschel nets tested did not differ from the conventional knotted cotton nets.

For two of these sets the graphs showing the number of gilled fish in each net are given in Fig. 9. The knotless Raschel nets are marked by underlining. In the other sets the position of the nets under test in the fleet of nets was also altered. As can be seen from the graphs the quantity of the catch in the knotless nets fits well in the catch distribution of all nets in the whole fleet and the catching efficiency of both net types can therefore be considered equal. This is of interest because knotless Raschel nets, due to their lower weight, are easier to handle.

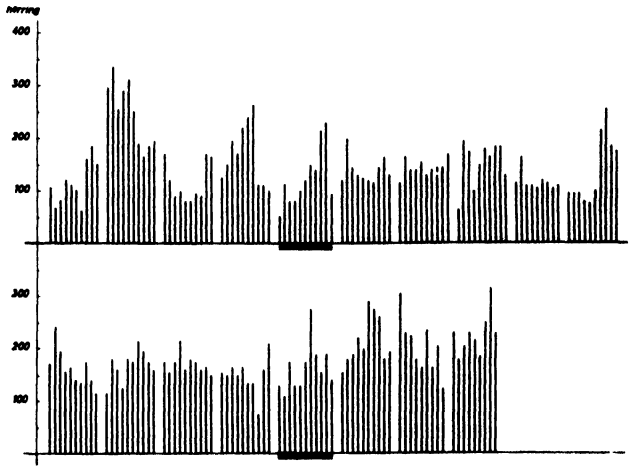

Fig. 9. Example of graphical evaluation of the catches in a fleet of herring driftnets for the determination of the comparative catching efficiency of single nets of different types. The tested nets are underlined

[4] These experiments have been made with the help of Vereinigte Glanzstoff Fabriken A.G., Wuppertal-Elberfeld, and Plutte, Koecke and Company, Wuppertal-Barmen. The Bremen-Vegesacker Fischerei-Gesellschaft kindly allowed the experiments to be conducted on one of their drifters by Dipl. Biol. Koops.

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Knotless Netting in the Norwegian Fisheries

by
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Abstract

The use of knotless netting in the Norwegian fisheries has increased from 17 tons in 1960 to about 200 tons in 1962. Initially all was imported but by 1962 19 machines for the production of knotless netting of Raschel type had been installed by Norwegian net manufacturers. Consequently only three per cent of the present consumption of knotless netting is now imported. High tenacity polyamide continuous multifilament yarn is used. Most of this netting has up until now been of small mesh size and used in purse seines for small herring and sprat. Table II gives denier values of equivalent plied (twisted) twines and Raschel; the latter tend to be of appreciably heavier denier for the same breaking strength, but a much smaller proportion of the twine length is used in the interlacings than in the case of knotting. At present prices in Norway, purse seines made from small-meshed knotless netting are 25 to 30 per cent cheaper than if made from knotted netting. However, with increasing mesh size, a point is reached where knotted netting can be produced more economically on conventional machines.

Filets sans noeuds dans la pêche Norvégienne

Résumé

L'emploi de filets sans noeuds dans la pêche Norvégienne a augmenté de 17 tonnes en 1960 jusqu'à 200 tonnes en 1962. Au début, tous les filets sans noeuds étaient importés mais en 1962 les producteurs de filets norvégiens ont installé 19 machines pour la fabrication de ces filets, du type Raschel. De ce fait, trois pour cent seulement de l'actuelle consommation de filets sans noeuds, sont importés. Les fils sont faits de polyamide à haute tenacité, en multifilament continu. La majeure partie de ces filets ont des petites mailles et sont utilisés dans les sennes coulissantes pour le hareng et l'esprot. Le Tableau II donne les valeurs en deniers des fils équivalents, tournés et en tresse Raschel; le dernier est plus lourd en deniers pour le même force de rupture mais dans les entrelacs des mailles, on utilise une longueur inférieure à celle des filets noués. En Norvège à présent, les sennes coulissantes faites de filets sans noeuds, à petites mailles sont de 25 à 30 pour cent moins chers que les filets noués. Cependant, avec des mailles agrandies on parvient à obtenir sur des machines conventionelles, des filets noués plus économiques.

Redes sin nudos en la industria pesquera Noruega

Extracto

El empleo de redes sin nudos en la pesca Noruega ha aumentado desde 17 toneladas en 1960 hasta unas 200 en 1962. Inicialmente se importaban todas pero para 1962 los fabricantes noruegos habían instalado 19 máquinas para tejer redes sin nudos del tipo Raschel con lo cual solamente el tres por ciento de las redes sin nudos empleadas actualmente son de importación. Los hilos son de poliamidos de varios filamentos continuos de gran resistencia. Hasta ahora casi todas estas redes han sido de malla pequeña y se han dedicado a la construcción de artes de cerco de jareta para la captura de espadín o arenque pequeño. La Tabla II da los valores denier de hilos torcidos y Raschel equivalentes; los últimos tienden a ser de denier bastante mayor para igual resistencia en la rotura, pero se emplea una proporción menor de hilos en las ligadas que en el caso de las redes de nudos. Actualmente en Noruega las redes de cerco de jareta de malla pequeña sin nudos cuestan de un 25 a un 30 por ciento menos que las anudadas, pero con el aumento del tamaño de la malla se llega a un punto en el que las anudadas se fabrican más económicamente en las máquinas corrientes.

BECAUSE of very limited local production, knotless netting used in Norwegian fisheries since 1960 has been mainly imported. Annual consumption of this type of netting (about 17 tons in 1960) gradually increased to almost 200 tons in 1962, as can be seen from Table I.

By 1962, 19 machines for making knotless netting had been installed by Norwegian net manufacturers, and imports were gradually reduced to only 6·7 tons in 1962, —about three per cent of the total knotless netting used that year. Norwegian knotless netting is mainly made of high tenacity polyamide continuous multifilament yarn, and most of it has been of the small mesh type used in purse seines for small herring and sprat.

TABLE I—Import, production, and consumption of knotless netting in Norway 1960-1962

	1960	1961	1962
Imported polyamide knotless netting, tons	15·0	82·1	6·7
Knotless netting locally produced from imported polyamide yarn	1·6	86·3	192·5
Total Consumption	16·6 tons	168·4 tons	199·2 tons

When knotless netting was first introduced at the beginning of 1960, experiments were carried out by inserting sections of knotless netting in the purse seines made traditionally of knotted netting. This type of netting has also been used on a smaller scale in purse seines for big herring which have a somewhat larger mesh size, as well as in shrimp trawls and other gear.

The knotless netting used is of the warp knitted type, produced on Raschel type machines, mainly of six-bar patterns. This construction method allows a great variety of mesh shapes, all based on the same yarn size, depending on the number of interlacings; this in turn influences apart from shape of mesh, also the strength and weight of netting. With only one or two interlacings at the joints, the meshes will be square as with knotted netting; by increasing the number of interlacings the mesh becomes hexagonal in shape. The square-shaped mesh seems to be the best as it provides equal mesh bars in all directions.

Experience in making knotless netting indicates that the best ratio of strength to weight is got by using filament yarn of the same count throughout in each section, i.e., by not mixing different yarn counts in one netting construction. Basic yarns used for different types of netting are standard counts available in polyamide yarn, such as 210d, 300d, 420d, 630d and 840 denier. Table II gives the Raschel construction denier values which can be substituted for common plied twines. The indicated total denier is the approximate value and takes into account the shrinkage of the yarn due to twisting in plied twines and to knitting in Raschel construction respectively.

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Knotless Fishing Nets on Raschel Equipment in Italy

Abstract
At the end of 1962 about 20 Raschel looms were in operation in Italy. Each machine has a mean capacity of 30,000 kg per year. The production of knotted nets of polyamide fibre has, in the past three years, averaged 500 tons per year in Italy. The main reason for the rapid introduction of the Raschel method is lower production costs due to saving in material and higher operating speed, ranging from 350 courses per minute (eight guide-bars) to 600 courses (four guide-bars); the coarser the yarn, the fewer are the courses in the unit length. Depending on the thread counts, the production of 100 kg of net on a modified Raschel machine, four guide-bars, 700 meshes, takes from three hours (210/90) to 22 hours (210/4). The smaller the mesh, the more apparent the advantage of the Raschel method becomes; 40 mm is considered the break-even limit, except for nets made of high-denier yarns. In Italy, knotless nets are less expensive than knotted for almost all mesh dimensions. High tenacity polyamide multifilament yarns, bright 210 denier (and multiples) are generally used. The best combination of denier/interlacing/machine gauge has not yet been determined and is still the subject of research. Run-proof nets are aimed at but not yet achieved. Heat-setting is often still used according to the technique for knotted nets but equipment for continuous dry setting is being developed.

Filets sans noeuds produits sur equipement Raschel en Italie

Résumé
A la fin de 1962, environ 20 métiers Raschel fonctionnaient en Italie. Chaque machine produit, en moyenne, 30.000 kilos par an. La production de filets sans noeuds en fibre polyamide, pendant les trois dernières années a été en moyenne de 500 tonnes par an pour l'Italie. La raison principale de l'introduction rapide de la méthode Raschel est le prix de revient de production plus bas. La méthode Raschel en effet, permet une économie de matériel et une vitesse d'opération plus élevée, entre 350 et 600 courses par minute; plus grossier sera le fil, moins nombreuses seront les courses par unité de longueur. Selon le nombre des fils, la production de 100 kilos de filet sur une machine Raschel de type modifié, quatre barreaux de guide, 700 mailles, demande de trois heures (210/90) à 22 heures (210/4). L'avantage de la méthode Raschel est plus apparent pour les petites mailles; dès 40 mm, il devient plus coûteux que pour les filets noués exceptés pour les filets faits de fil de fort denier. En Italie

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TABLE II—Denier values of equivalent plied twines and Raschel twines

Twine No. Denier	Total Denier in twine	Raschel Construction Denier	Total Denier in Raschel
210/2×2	900	210/3	1260
210/2×3	1400	300/3	1800
210/3×3	2140	420/3	2520
210/4×3	2800	630/3	3780
210/5×3	3600		
210/6×3	4300	840/3	5040

Of the total length of twine used in making a mesh, a substantial part goes into the knot in knotted netting and this portion increases as the mesh size becomes smaller. In Raschel netting a much smaller proportion of yarn or twine length is used in interlacings. Therefore, the ratio of total denier for plied twine and Raschel twine does not represent the correct ratio between the total material in the same size panels of knotted and knotless construction. Furthermore, owing to the different construction of the joints (knots and interlacings), the percentage of twine strength lost in the joints cannot be compared (see Table III).

Production capacity of Raschel machines, compared with that of machines for producing conventional knotted netting, presents most favourable conditions for producing small mesh knotless netting (as used in purse seines) and the bulk of knotless netting used in Norway has been for such nets.

As mesh size increases, a point is reached where knotted netting can be produced more economically on conventional machines. Where production costs for both types of netting are the same, the deciding factors must then be the serviceability of the netting in operation, such as bulk, resistance, etc. As knotless nets are rather new in Norwegian fisheries, it is most difficult to secure a valid opinion. However, the increasing demand for knotless netting shows the great interest created. At present prices in Norway, a complete purse seine made from small-meshed knotless netting will be approximately 25 to 30 per cent cheaper than if made from the conventional type of knotted netting.

TABLE III—Weight and strength of comparable knotted and knotless netting

Mesh strengths and weight of panel 600 meshes × 100 metres

Polyamide knotted netting (single knots) Mesh size: 35-7·5 mm			Polyamide, knotless netting		
Twine No. Denier	Weight (kg)	Wet mesh strength (kg)	Raschel Denier	Weight (kg)	Wet mesh strength (kg)
210/2×2	16–20	5·5–6·0	210/3	22·3	5·5–6·0
210/2×3	25–31·5	7–8	300/3	32·0	7–8
210/3×3	37–50	11–12	420/3	44·6	12–13
210/4×3	53–72	14–15	630/3	66·9	17–18
210/5×3	71–96	17–18			
210/6×3	91·5–123·5	21–22	840/3	89·2	24–25

The knotless netting is given preservative or stiffening treatment similar to the knotted netting; coal-tar, bonding, dyeing, etc., are used depending on the end use. Coal-tar increases the mesh strength of knotted netting but this effect is less noticeable with knotless netting.

les filets sans noeuds sont moins chers que les filets noués pour presque toutes les dimensions de mailles. Les fils de polyamide multifilaments de haute ténacité, brillants, de 210 denier (et multiples) sont généralement utilisés pour la fabrication des filets. La meilleure combinaison de denier/tricotage/numéro de machine n'a pas encore été déterminée et la recherche se poursuit. On essaie de produire des filets qui sont indémaillables mais on n'y est pas encore parvenu. La fixation par la chaleur est encore utilisée très souvent suivant la technique des filets noués mais l'équipement pour la fixation à sec est toujours en cours de développement.

Redes sin nudos producidas por las maquinas Raschel en Italia

Extracto

A fines de 1962 funcionaban en Italia unos 20 telares Raschel. Cada telar tiene una capacidad media de 30.000 kg al año. En los últimos tres años se han fabricado en Italia, por término medio, 500 tons de redes anudadas de fibras de poliamidos. La principal razón de la rápida propagación del método Raschel es que los costos de producción son más bajos debido a un ahorro de material y a una mayor velocidad de funcionamiento que va de 350 puntos por minuto (ocho barras-guía) a 600 puntos por minuto (cuarto barras-guía). Cuanto más grueso es el hilo menos puntos hay que dar por unidad de longitud. Según el número del hilo, la producción de 100 kg de red en una máquina Raschel modificada de cuatro barras-guia, 700 mallas, tarda de tres horas (210/90) a 22 horas (210/4). Las ventajas del método Raschel son mayores cuanto más pequeña es la malla, considerándose la de 40 mm como el límite, excepto en el caso de redes hechas de hilo de más denier. En Italia las redes sin nudos son más baratas que las anudadas en casi todas las dimensiones de malla. Generalmente, se emplean poliamidos de varios filamentos de 210 denier (y múltiples). Todavía no se ha determinado la mejor combinación de denier/ligamento/y calibre de la máquina, por lo que continúan los estudios. Tampoco se ha conseguido fabricar redes en las que no se corran los nudos. Todavía se usa con frecuencia la fijación térmica según la técnica para las redes anudadas, pero se fabrican máquinas para la fijación continua en seco.

FROM West Germany the Raschel method of manufacturing knotless fishing nets spread quickly to other European countries. In Italy lately, and especially last year, all the most important net manufacturers have added Raschel looms to the conventional knotting machines.

At the end of 1962, about 20 Raschel looms were in operation.

Most of these looms have six guide-bars (also four and eight), 124-inch and 139-inch width (also 100-inch), while gauges range between 18 and 28 needles per two in. The most popular type is 24 gauge.

For a country like Italy, where the production of knotted nets (polyamide fibre) has averaged 500,000 kg per year in the last three years, this number of Raschel looms is undoubtedly high considering the production capacity of these machines—on either light or heavy nets, a machine has a mean capacity of 30,000 kg per year.

The reason for this new trend is economic; production costs will be lower with a considerable saving of material by eliminating knots. The weight of knots is often out of proportion to the weight of net. Elimination of knots becomes more important as meshes grow smaller and the threads become coarser. In addition, towing speed can be noticeably raised.

Actual knitting speed ranges, roughly, from 600 courses (four guide-bars) to 350 courses per minute (eight guide-bars).

The quantity of net produced in the unit of time (most important as nets are sold by weight) depends also upon the number of courses, the width of the machine and the denier of the yarn used. The coarser the yarn, the fewer are the courses in the unit length; the runnage per hour for 840 den (8-9 courses per cm) is about twice that of 210 den (15-16 courses per cm), while the weight of the net produced is three times as much (Table I).

Table I—Production of 100 kg of net on a modified Raschel machine, four guide-bars, 28 gg, 700 meshes (thread counts are expressed in deniers, as is customary for the twines used in knotted fishing nets)

210 den: (210×4)=22 hr	840 den: (210×18)=8 hr
(210×6)=16 „	(210×27)=5 „
(210×9)=12 „	(210×48)=4 „
	(210×90)=3 „

There are two advantages: in material and in processing. Firstly, for Raschel machines either flat or low-twist yarns are used, whereas for knotted net machinery higher priced twine is required. Average price ratio of ply yarns (on beams) versus twine is 1/1·2. Secondly, Raschel looms are equipped with warp beams on which a great length of yarn is wound; this means that they can be operated for a much longer time than conventional machines, the performance of which is limited because of low bobbin capacity.

The advantage of the Raschel method over the conventional one becomes more apparent the smaller the mesh. Actually, in the first case the yield, which does not depend upon the mesh size, is inversely proportional to the number of courses per cm; in the second case the yield increases with the size of the mesh. Admittedly 40 mm is the limit beyond which the knotting machines become more economical. It is clear, however, that this limit increases considerably in the case of nets made of high denier yarns.

In Italy, knotless nets are less expensive than others for almost all mesh dimensions, as indicated in Fig. 1 which shows the price in lire per kilo of the two types of commercial nets on the basis of mesh size and weight of the net.

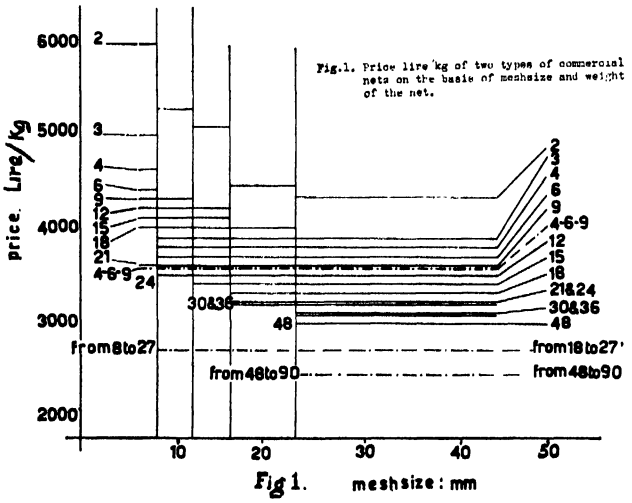

Fig.1. Price lire/kg of two types of commercial nets on the basis of meshsize and weight of the net.

Fig 1.

In the manufacture of knotless nets high tenacity polyamide multifilament yarns bright 210 den (and its multiples 420 and 630 den) and 840 den (and its multiples up to 8,400 den) are generally used. For very fine nets also 100 den finds some use.

The most important characteristics of these yarns are shown in Table II (the figures refer to Rhodiatoce 'Nailon'[1] yarns).

TABLE II

Denier	Tenacity g/den	Extension at break %	Breaking length/ km	3-ply yarns breaking length/km	Knot strength %
210	7·5	22	67	59	68
840	8·2	16	73	56	55

Singles are generally twistless or low-twist (130-160 turns/metre). As a rule the twist for ply yarns ranges from 150 to 110 turns/metre. Usually the yarns are supplied on knitting beams. The choice of the denier is dependent on the type of net desired and on the gauge of the loom.

Table III shows the relation existing between these data. (The figures refer to a six guide-bar machine.)

Construction of knotless nets does not differ substantially from that adopted in other countries. Nets are composed of many threads forming the mesh sides, which are interlaced at regular intervals at "cross-over points" at the apex of the mesh. Threads correspond to twines in the same way as cross-over points correspond to knots in the knotted nets.

[1] 'Nailon' is the registered trademark of Società Rhodiatoce S.p.A. in Italy.

In the most common version, a thread is formed by three ends; two laid-in threads (1 and 3) and one (2) looped, entwined together. The laid-in threads are in an almost rectilineal position, the looped threads (2) follow a more complicated path (Fig. 2).

Owing to this construction, the task of bearing the net load is mostly carried by laid-in threads, the length of which is about one-fourth that of the looped thread (2). In general, the looped threads (2) may be lower of denier than the other two. Yet, as the exact value of the possible reduction in count has not been established so far, this technique is not adopted in Italy at present.

At the mesh apex there are different types of joints, depending upon the way the yarns are interlaced. The more complex the structure of these joints, the stronger and more durable they are, according to whether only the looped threads or also the laid-in threads are entwined and depending upon the number of binding points (generally two to four).

In Fig. 3 the most common stitches used in Italy are shown.

It has not been established as yet which are the most suitable constructions for maximum mesh wet-strength. To avoid damaging the catch, round threads are being developed, but this is only a minor point.

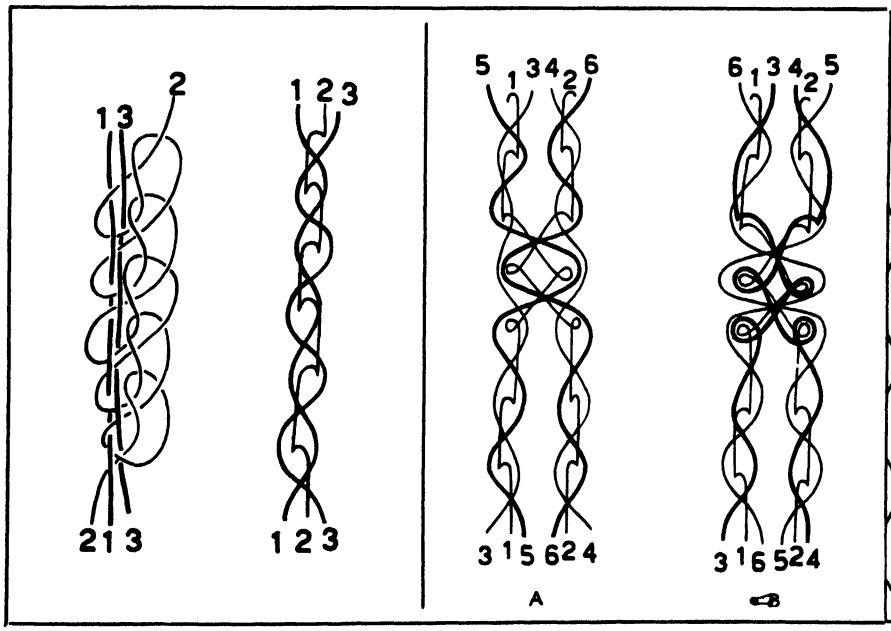

Fig. 2. *Fig. 3.*

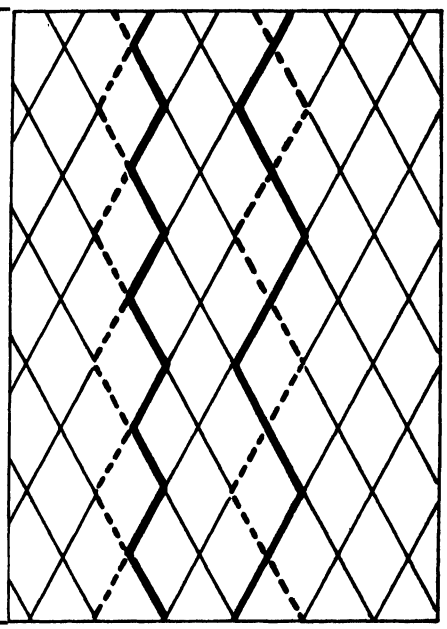

Fig. 4.

TABLE III

Max. denier	gauge	Needles per in	width 100 in needles	width 100 in meshes	width 124 in needles	width 124 in meshes	width 139 in needles	width 139 in meshes
840×10=8400	8	4	400	200	496	248	556	278
840×6=5040	12	6	600	300	744	372	834	417
840×4=3360	14	7	700	350	868	434	937	486
840×3=2520	16	8	800	400	992	496	1112	556
840×2=1680	18	9	900	450	1116	558	1251	625
840	24	12	1200	600	1488	744	1668	834
210×3=630	28	14	1400	700	1736	868	1946	973
210×2=420	32	16	1600	800	1984	992	2224	1112

The best combination of denier/interlacing/machine gauge has not yet been found and research is being carried out in this direction. The field is still too new. For example, it has already been seen that interlacing A (and almost all new machines are equipped with the glider chains for this interlacing) does not give very satisfactory results. In particular the threads have a tendency to ladder when some ends break. For this reason several net manufacturers favour stitch B.

The system, followed by some manufacturers, of letting yarns (2) pass from one mesh to another (Fig. 4) does not seem to produce much stronger joints but makes them more resistant to laddering. Absolutely run-proof nets have not yet been produced. Actual experience, though limited, has shown, however, that heat-setting and impregnation of the nets ensure satisfactory performance in this respect. Often heat-setting is still carried out according to the technique used for knotted nets, i.e., by wrapping the net around a steel cylinder and setting it in either boiling water or steam. Equipment for continuous dry setting by means of hot air is, however, being developed.

Table IV gives figures of the outstanding characteristics of several types of knotless nets with type A joint made from 'Nailon' yarn. For two of them a direct comparison is established with corresponding knotted nets.

YARNS		BRAIDS (TWINES)						NETS				
Nominal denier		diameter	actual denier	C.R. dry	C.R. wet	L.	courses/cm.	mesh size	weight (1)	breaking strength dry (2)	breaking strength wet	tearing strength dry (3)	tearing strength wet	price ratio (4)
T.	C.	mm	den	kg	%	km		mm	g	kg		kg		
420	420	0,82	3690	8,3	94%	20,2	12	18	8,8	16 ↓ 14 13 → 12		7	6	100
210x6		0,65	2100	12,4	88%	53	"	17,5	7,9	14 ↓ 12 14 → 11		10	8	97
840	840	1,2	7360	16	94%	19,8	8	17	17,8	30 ↓ 29 23 → 21		13	12	100
210x21		0,98	5400	30	90%	51	-	22	15,8	24 ↓ 22 21 → 19		23	19	158
2520	3360	2,1					5,5	13	88	125 ↓ 97 93 → 83		48	47	

Table IV

The small figures refer to knotted nets corresponding to the knotless nets considered.

CAPTION: - T = laid-in threads
C = looped threads
CR = breaking load
L = breaking length

(1) 1 m x 10 meshes
(2) mesh specimens: 20 cm. x 1 mesh : ↓ lengthwise ; → crosswise
(3) according to drawing

(4) assuming 100 as the price of the knotless net.

Résistance à la Rupture de Filets sans Noeuds

Résumé

La construction de filets sans noeuds du type Raschel s'est développée en Europe depuis la guerre. Un des avantages de ces filets sur les filets noués de type traditionnel est le manque de stabilité des noeuds de ces derniers. Les filets peuvent être construits sur des machines Raschel utilisées par l'industrie textile depuis de nombreuses années. Pour les filets de pêche les barres des mailles sont composées d'un ou plusieurs composants tricotés, supportés par des composants entrelacés et il existe différentes façons de faire la connexion des mailles. Jusqu'ici les filets sans noeuds ont une résistance à la rupture plus faible dans le sens transversal que dans le sens longitudinal. A la suite d'une étude faite en Italie, un nouveau type de filet sans noeuds a été développé dont la force de rupture est à peu près égale dans toutes les directions. La communication décrit la construction de ce filet dont les composants simples se divisent à chaque intersection de mailles, suivant une séquence sinueuse pendant laquelle, non seulement le nombre de composants formant les barres des mailles mais aussi le fil des barres, varient ce qui fait que les forces s'exerçant sur le filet sont réparties sur tous les fils. Les résultats des épreuves montrent que pour le type normal de filet sans noeud perd de 15 à 20 pour cent de résistance transversale tandis que la nouvelle construction de filet ne perd que 4,5 pour cent en comparaison avec la direction longitudinale.

Breaking strength of knotless webbing

Abstract

The construction of knotless net of the Raschel type has developed in Europe since the war. One of the advantages of knotless nets over the traditional knotted types lies in the knot-fastness. The nets can be made on modern Raschel machines used for many years in the textile industry. For fishing nets the mesh bars are composed of one or more knitted components supported by intertwining components and there are various ways of making the mesh connections. In most cases the webbing has a lower strength when pulled across the connections. Resulting from a study made in Italy, a new type of knotless net was developed which has almost equal strength in all directions. The paper describes the construction of such netting whereby the number of straight components making up the bars divide at each mesh connection according to a regular sequence. The knitted components as well as the straight furthermore change from bar row at regular intervals, resulting in a thorough spread of the components as knitting progresses. Test results showed that the usual type of knotless webbing had 15 to 21 per cent less breaking strength across the connections than with the connections. The new type of webbing loses only 4·5 per cent when tested in the across the connections direction.

Resistencia a la rotura de redes sin nudos

Extracto

La fabricación de redes sin nudos de tipo Raschel comenzó en Europa después de la guerra; con ellas se ha vencido el grave inconveniente del deslizamiento o corrimiento de nudos que ocurre en las tradicionales. Pueden fabricarse en las máquinas Raschel que emplea la industria textil desde hace varios años. Para las redes de pesca las mallas las forman uno o más componentes trenzados sustentados por componentes entrelazados y existen diversas maneras de hacer las conexiones de las mallas. Hasta ahora los paños sin nudos tenían una resistencia a la rotura más débil en el sentido transversal que en el longitudinal. Como resultado de un estudio realizado en Italia se fabrica un nuevo tipo de redes sin nudos en el que la resistencia es casi igual en todas las direcciones. Describe la ponencia la fabricación de estas redes en las que los componentes sencillos se dividen en cada intersección de mallas según una serie sinuosa en la que el número de componentes que forman las mallas, así como el hilo de éstas, varían de manera que las fuerzas a que está sometida la red se reparten por todos los hilos. Los resultados de los ensayos son que la clase normal de redes sin nudos tienen de 15 a 21 por ciento menos resistencia transversal, en tanto que con la manera nueva de fabricar sólo se pierde el cuatro por ciento de resistencia cuando la red se somete a esfuerzos transversales.

by

Francesco Pianaroli

LA fabrication des filets sans noeuds de type Raschel s'est développée en Europe depuis la fin de la guerre. Ces filets se sont révélés très utiles par suite du manque de stabilité des noeuds des filets traditionnels fabriqués avec des fils en fibres synthétiques. Un autre avantage des filets sans noeuds est la dimension constante des mailles. Ces filets pouvant être tricotés sur des métiers Raschel normaux, leur emploi dans le domaine de la pêche s'est rapidement développé.

Les filets sans noeuds de type Raschel sont fabriqués de la façon suivante: les fils tricotés en chaînette, s'entrelacent à des distances déterminées pour former les mailles. Les fils tricotés servant de base peuvent être renforcés par l'insertion d'un ou plusieurs fils simples, suivant différentes techniques. Il existe aussi plusieurs méthodes de connexion des mailles et parmi les plus typiques, on peut citer celle proposée aux U.S.A. par M. Henry Goldsmith et celles utilisées par quelques fabricants européens et japonais, depuis 1955.

Aujourd'hui, la qualité des filets de pêche produits dans le monde est assez satisfaisante bien que l'expérience ait démontré qu'il était souhaitable d'augmenter encore les caractéristiques de résistance et de durée. En Italie, des essais effectués en Laboratoire ont confirmé que par la recherche, on pouvait encore améliorer la résistance des entrelacements.

D'une manière générale, la résistance des filets sans noeuds à la rupture par suite de traction transversale est de beaucoup inférieure à la résistance à la traction longitudinale. En outre, la tension n'est pas également distribuée sur les fils composants, dans les barres des mailles aussi bien que sans les connexions.

Les études effectuées avaient pour but:

(a) d'augmenter la résistance des filets par une meilleure distribution des forces;

(b) d'uniformiser la résistance des fils élémentaires dans les entrelacements afin de lutter aussi bien contre les tractions longitudinales que transversales;

(c) de créer une suite de points d'interchangement des fils uniformément répandus dans le filet et avec la plus grande densité possible, ce qui augmentera la résistance à la rupture du filet par suite de forces transversales exercées sur les entrelacements.

De très bons résultats ont été obtenus par la méthode que nous décrivons ici dans ses grandes lignes. Les filets sont construits par des métiers "Raschel" normaux et les barres des mailles sont constituées par des fils simples et des fils tricotés en chaînette, les premiers s'entrelaçant et se croisant dans les seconds de telle façon que

lorsque le filet est soumis à ure force, la tension est répartie uniformement sur tous les fils composants.

Pour obtenir ce résultat, des paires multiples de "rangs" formant les mailles dans le sens de la construction du filet ont été entrelacées de manière à ce que les fils puissent s'entrelacer et se séparer et ce, aussi bien pour les fils tricotés en chaînette que pour les fils simples.

Ainsi, dans une maille les deux barres convergentes de gauche et de droite forment une demi-maille; dans chaque barre, les fils composants continuent conjointement chacun avec sa séquence sinueuse typique, jusqu'à un noeud du premier rang; à ce moment on procède à un échange multiple parmi les aiguilles des groupes de fils voisins, en chaînette, de telle sorte qu'après s'être plusieurs fois croisés pour constituer l'entrelacement, les fils passent au rang suivant, dans la "file" voisine respectivement droite et gauche, pour former la barre inverse correspondante d'un nouveau rang. En même temps, les fils simples de chaque barre, après s'être croisés dans l'entrelacement, se divisent en deux groupes inégaux, les uns passant dans le rang suivant à la "file" de droit et les autres dans celle de gauche pour former, avec les fils tricotés, les barres d'un nouveau rang. Successivement, dans les entrelacements du deuxième rang, la même division des fils simples se reproduit mais les groupes s'invertissent tous les deux rangs. En même temps, au deuxième rang les groupes de fils tricotés en chaînette, de deux barres voisines font un double échange sur les aiguilles, chacun d'eux restant à la même file, pour former le troisième rang. Les entrelacements du troisième rang seront donc une répétition des mouvements cités pour le premier rang, mais le nombre de fils de chaque file sera interverti. Le schéma des mouvements des fils est représenté dans la figure 1.

Les filets construits selon cette méthode ont donné des résultats très satisfaisants en ce qui concerne la résistance à la rupture contre les forces de toutes directions. Le petit tableau ci-dessous donne les résultats obtenus sur différents types de filets examinés. Le filet noué utilisé était fabriqué en fibre polyamide 66 210d/9, de 7 g/d de ténacité et comportait 1000 mailles de largeur sur un m de hauteur et pesait 0,700 kg. A une ténacité de 7 g/d, la charge théorique de rupture de chaque fil aurait dû être $210 \times 9 \times 0{,}007 = 13{,}330$ kg mais les valeurs trouvées pour les charges de rupture longitudinale et transversale étaient de 8 kg et 7,200 kg respectivement. Cette diminution de résistance est due à la perte de 40 pour cent dans les noeuds.

Des essais ont été effectués sur quelques types de filets sans noeuds, fabriqués en Italie et dans d'autres pays d'Europe. Sur des sections de filet de 1000 mailles sur 1 m, pesant chacune entre 690 et 720 grammes, les charges de rupture ont été très inférieures à celles des filets noués et accusaient une perte de 15 à 21 pour cent dans le sens transversal.

Des essais sur un filet sans noeuds construit d'après le système décrit plus haut ont montré que la résistance à la rupture sous des forces transversales et longitudinales était très supérieure à celle des autres constructions.

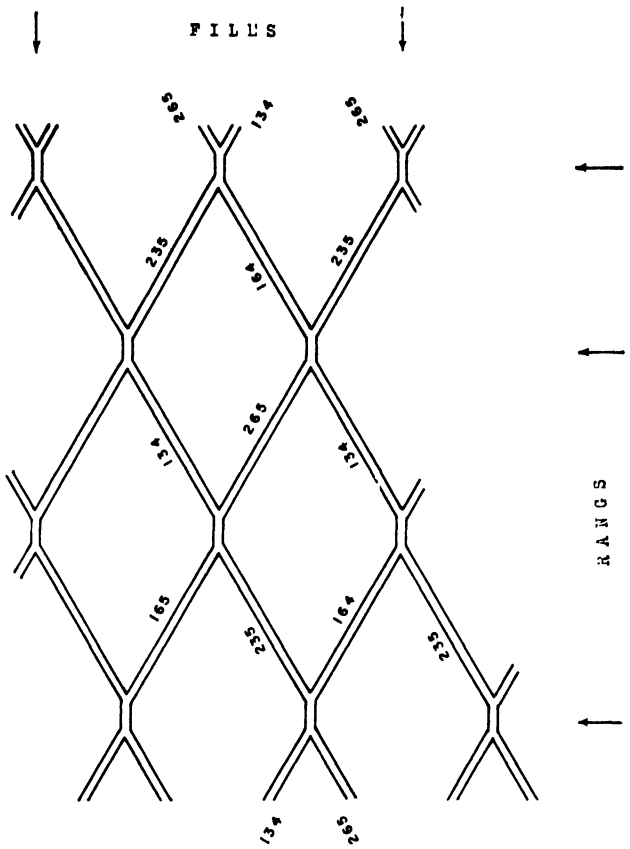

Fig. 1. Répartition des fils composants dans la formation des mailles.

Type de filet	Charge de rupture longitudinale en kg/fil	Charge de rupture transversale en kg/fil
Filet noué, traditionnel poids: 0,7 kg/1000 mailles haut. 1m	8	7,200
Filet sans noeuds, en général	6,100—7,350	4,800—6,250
Filet sans noeuds construit d'après le système énoncé	9	8,600

Le résultat le plus remarquable est qu'avec la méthode de fabrication décrite, la résistance à la rupture est augmentée, bien que la résistance de certaines barres soit moindre que celle des autres constructions. Ceci a été obtenu en proportionnant les fils simples et tricotés composant les barres des mailles et en faisant participer plus étroitement les fils simples dans la formation des entrelacements.

Monofilaments in Fishing

by

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Abstract

Synthetic fibres became widely used in the fishing industry several years ago, but mainly in the form of twines made of continuous multifilaments (in the range of 2-25 denier/filament). During the last few years a major breakthrough has been witnessed in the use of monofilaments, i.e., filaments of 50-1,000 denier. Before monofilaments could make any dramatic impact on the traditional market, polymers had to be produced giving fibres with the following characteristics: (a) sufficient flexibility, (b) high tenacity, (c) capability of manufacture at high speed and (d) availability at commercially attractive prices. The bending moment of a circular monofil varies in proportion to the fourth power of the diameter. Shapes of monofil cross-sections are now mainly circular, but rectangular as well as ribbon-like cross-sections have been used in an endeavour to increase flexibility and firmness of knot. However, it seems that to be effective in this way the cross-section must be extended to a ribbon-like form, but then other factors, notably abrasion resistance, can become critical. In netting, the wet knotted strength is of major importance, as well as the load/extension characteristics. These values are given in tables for monofilaments of polyvinylidene chloride, nylon, polyethylene and polypropylene, as well as changes in tenacity at varying temperatures. High tenacities can be achieved through stretching during spinning, but at the expense of extensibility, and a favourable balance must be struck between these properties. From experiments it appears that a load of up to two g/den is commonly applied to monofilaments during normal trawling operations, and the extensibility at such loads is expressed in graphs in this paper. Test values are also given for other properties such as creep, elastic recovery and impact strength, stiffness, knot stability, abrasion resistance, towing resistance, rotproof characteristics and resistance to sunlight. The use of monofilaments in certain types of fishing gears is discussed, such as in Danish seines, wing trawls, midwater trawls, deep-sea trawls, shrimp nets, lobster pots, salmon trapnets and longlines, as well as the use of monofilaments for ropes.

Monofilaments dans la pêche

Résumé

Depuis quelques années les fibres synthétiques sont bien connues dans l'industrie des pêches, principalement sous forme de fils retordus en filaments continus (entre 2-25 denier/filament). Au cours de ces dernières années l'utilisation des monofilaments c'est-à-dire des filaments de 50-1.000 deniers s'est développée considérablement. Pour que les monofilaments deviennent acceptables par le marché traditionnel, il fallait des polymers donnant des fibres ayant les caractéristiques suivantes: (a) flexibilité suffisante; (b) haute résistance à la rupture; (c) possibilité de fabrication accélérée; (d) disponibilité à des prix intéressants. Le moment de fléchissement d'un monofil circulaire varie en proportion à la 4ème puissance de son diamètre. Les coupes des monofilaments sont normalement circulaires mais des formes allant du rectangle jusqu'au ruban ont été utilisées au cours d'essais pour accroître la flexibilité et la fermeté des noeuds. Il semble que pour ces deux caractéristiques, les fils en forme de ruban sont les plus efficaces mais alors d'autres facteurs deviennent critiques, notamment la résistance à l'abrasion. La force de rupture du filet noué mouillé est de la plus grande importance de même que les caractéristiques de force/extension. Ces valeurs sont données dans des tableaux pour des monofilaments de polyvinylidène chloride, nylon, polyéthylène et polypropylène ainsi que les variations de résistance à la rupture à des températures différentes. De hautes forces de rupture peuvent être obtenues par étirage pendant le filage mais au détriment de l'extension de sorte qu'un équilibre favorable doit être trouvé entre ces propriétées. Les résultats des expériences ont montré qu'une force de deux g/den est normalement appliqué aux monofilaments pendant des opérations normales de chalutage et l'extensibilité sous de telles forces est exprimée dans un graphique. Sont données également les valeurs déterminées au cours des expériences pour les autres propriétés des monofilaments telles que: reprise élastique, résistance aux chocs, raideur, stabilité des noeuds, résistance à l'abrasion, résistance à l'avance, caractéristiques de pourrissement et résistance aux rayons solaires. L'utilisation des monofilaments dans certains types d'engins de pêche tels que les sennes danoises, les différents types de chalut, les filets à crevettes, les nasses, les trappes pour saumon, les palangres aussi bien qu'en corderie est traitée dans cette communication.

Los monofilamentos en la pesca

Extracto

La industria pesquera emplea mucho desde hace varios años fibras sintéticas, principalmente en la forma de hilos hechos de multifilamentos continuos (en la gama de 2-25 denier/filamento). En los últimos años se hand hecho prodigiosos adelantos en la fabricación de monofilamentos, y actualmente se obtienen de 50 a 1.000 denier. Antes de que estos monofilamentos pudieran entrar en el mercado tradicional, tuvieron que producirse polímeros que dieran fibras con las siguientes características: (a) suficiente flexibilidad, (b) gran tenacidad, (c) capacidad de manufactura a gran velocidad y, (d) disponibilidad a precios interesantes. El momento de flexión de un monofilamento circular varía en proporción con la cuarta potencia del diámetro. Las formas de las secciones transversales de los monofilamentos son principalmente circulares, pero también se emplean rectangulares y como cintas, para tratar de incrementar la flexibilidad y firmeza del nudo. Sin embargo, para que sea eficaz, la sección transversal debe ser como una cinta, pero entonces entran en juego otros factores, principalmente la resistencia a la abrasión, que pueden llegar a ser críticos. En los paños para redes la resistencia del nudo húmedo es de la mayor importancia, y también lo son las características de carga y estiramiento. Estos índices se dan en tablas para monofilamentos de cloruro de polivinilideno, nylon, polietileno y polipropileno, así como los cambios en la tenacidad a diversas temperaturas. Puede lograrse gran tenacidad estirando mientras se teje pero a expensas de la extensibilidad, por lo que hay que encontrar un equilibrio favorable entre estas propiedades. De los experimentos se deduce que una carga hasta de 2 g/den se aplica normalmente a los monofilamentos durante la pesca al arrastre; a extensibilidad a tales cargas se expresa gráficamente en esta comunicación. También se dan valores obtenidos en ensayos de otras propiedades como deslizamiento, recuperación elástica y resistencia a los impactos, rigidez, estabilidad del nudo, resistencia a la abrasión y al remolque, resistencia a la podredumbre y a la luz del sol. Se examina el empleo de monofilamentos en artes de pesca como los de arrastre danses, pernadas de artes de arrastre, artes flotantes, artes para la pesca de gran altura, redes camaroneras, nasas langosteras, trampas y palangres salmoneros, y el empleo de monofilamentos para cuerdas.

WE deal in this paper with markets and applications held traditionally by hard fibres, manila, hemp and sisal, and soft fibres, linen and cotton. Over a period of years the industry had built itself up to a high degree of efficiency with stability in price.

Developments in fibre-forming polymers began to break new ground in the post-war period, nylon being first as a fibre possessing exceptionally high tenacity. Other properties were excellent impact and energy absorbing characteristics, together with resistance to rotting.

These fibres, which were already established in apparel uses, possessed excellent flexibility due to their fineness (a range of 5-25 denier/filament). The logical development was the use of multifilament yarns in place of soft fibres, linen and cotton, followed by the introduction of monofilament yarns. These monofilaments were in the range 50-1,000 denier/filament.

Having made the distinction between the multifilaments and monofilaments, we follow the progress of monofilament materials in relationship to other synthetic yarns. Before monofilaments could make any dramatic impact on traditional markets, polymers had to be produced, giving fibres having these characteristics:

(a) Sufficient flexibility to be capable of yarn, strand and net production on conventional machinery.
(b) A high tenacity.
(c) The capability of manufacture at high speed.
(d) Availability at a commercially attractive price.

Nylon monofilaments

Earliest monofilaments were made from nylon and were soon used for very fine gillnets in Northern European lakes. They had the great advantage of high strength for small filament diameter and were relatively invisible in the water. Further development in larger diameter filaments was limited, firstly, by rapid increase in stiffness and, secondly by, commercial considerations, which tended to favour the promotion of multifilament yarns and staple fibres. More recently, in Germany, where nylon has reached a high level of acceptance, nylon monofilaments have been used in large rope structures alongside nylon multifilaments. The former confer on the rope a very high degree of abrasion resistance, whilst the multifilaments bear the major load.

It will be seen that the basic stiffness of nylon tends to limit its use as a fibre except in fine diameter or in large rope structures where flexibility is not so important. To some extent these remarks apply also to polypropylene, particularly when aiming for tenacities required by everyday applications.

Polyolefin monofilaments

It will be appreciated from the foregoing that a more widespread replacement of traditional fibres by monofilaments could occur when a sufficiently flexible filament in the higher denier range had been developed. Such a fibre did, in fact, emerge in the earlier days of the polyolefins. The earliest fibres produced were spun from conventional (low density) polyethylene and gave filaments of high flexibility but very low tenacity (in the range 1·0 to 1·5 gpd). With such a low tenacity there was little chance of use in cordage applications, and it was not until linear polyethylene had been spun that high tenacity filaments were possible. These gave tenacities of the order of 5-6 gpd but were rather less flexible than those produced from conventional polyethylene. It was possible, however, to produce right from the outset a complete range of twines and rope yarns, with the exception of very fine twines where the multifilament yarns still held their own.

By 1957/1958, nylon multifilament had secured a very prominent position in the netting field and was in widespread use in gillnets of all types, for purse seine nets, principally in Norway, and for herring driftnetting. All these end uses required excellent twine flexibility for effective fishing; nylon, and to a lesser extent the polyester fibres, provided this in ample measure. Although some synthetic ropes were in existence, their acceptance at this time in the fishing industry was not high and current usage was confined more to pure marine fields where nylon towing ropes and hawsers had proved very effective.

During the last few years, major breakthroughs in net and rope have been witnessed—much of it associated with the widespread use of monofilaments.

There has also been a pronounced narrowing of the price gap between the natural fibres and the man-made fibres. This review is intended to convey in straightforward terms to the twine maker, netmaker and trawler-owner, the considerations which a yarn producer has in mind when marketing a yarn intended for the cordage market. The technical properties of the yarns, allied to production aspects, are outlined in the following comparison of monofilament properties and references made to the economic considerations in some end uses.

Monofilament deniers, shape of cross-section, etc.

These usually fall within the range 100-4,000 den, the common ones in commercial use in fishing at present being between 100 and 1,000 den per filament (11 - 110 tex). The shapes of cross-sections are mainly circular but, in certain instances, rectangular cross-sections have been used with a width : depth ratio of approximately 3 : 1. More recently we have seen experiments with ribbon-like cross-sections, e.g., having a width : depth ratio of approximately 50 : 1, and also combinations of circular and ribbon-type cross-sections, e.g., round sections spaced at intervals across the cross-section of a continuous width of ribbon-like monofils.

Much work has been done on flat cross-sections with a view to increasing both the flexibility of twines and the firmness of the knots. In the former, the bending moment is reduced as a result of the thinner axis in one direction and increased flexibility results (the bending moment of a circular monofil varies in proportion to the fourth power of the diameter). In our experience, we have found little advantage in these respects, unless the cross-section is extended to a ribbon-like form and, in such cases, other factors, notably abrasion resistance, can become critical.

Strength

The strength of yarns or monofilaments is often quoted as a selling point and discussed in terms which suggest that this figure alone determines the strength of net, twine or rope made from same. In actual use, in a fishing net for instance, it would seem that the wet knot strength of the twine is a more proper indication of strength. Bearing in mind the vast range of twines and twine constructions in use, it falls upon the yarn manufacturer to devise his own standards. These are based on laboratory and practical tests and aim at an optimum relationship

between tenacity and extensibility for the particular end uses.

(a) Tenacity

Table I gives a general indication of the tenacity of monofils used in twines and ropes:

Polyvinylidene chloride fibres	2	g/den
Nylon	5—7	g/den
Polyethylene	5·0—7·5	g/den
Polypropylene	5—8·0	g/den

(In the case of nylon there is a loss in tenacity when wet)

Fig. 1 shows typical load/extension curves for these fibres (ref. "Textile World", 1962).

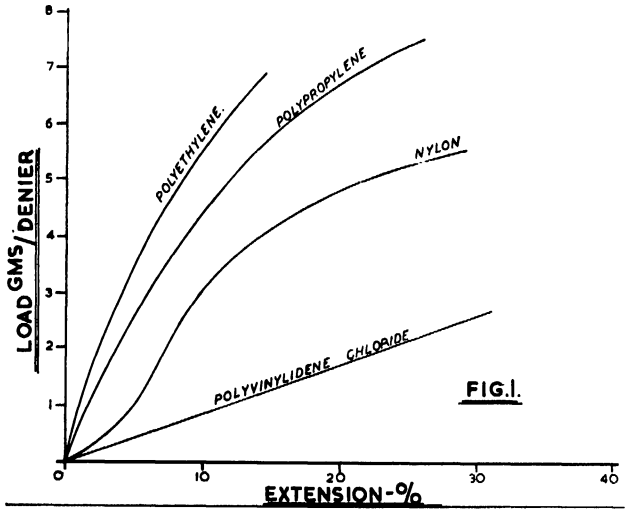

FIG.1.

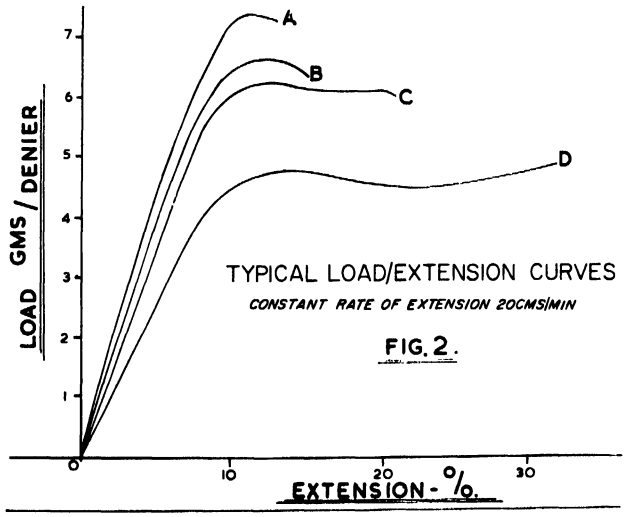

FIG. 2.

Fig. 2 illustrates the effect on tenacity of various stretch ratios applied to 'Courlene' high density polyethylene monofilaments during spinning.

(b) Effect of heat

The tenacity of thermoplastic monofilaments is also affected by heat but most values quoted relate to tests carried out under standard conditions at 20°C. Table II illustrates typical changes in tenacity (g/den) of some monofilaments at varying temperatures thus:

	'Courlene X3'	Polypropylene	Nylon	'Saran'
2°C	8·1	6·0	5·4	2·1
20°C	7·0	5·4	5·1	1·9
40°C	4·9	5·2	4·2	1·6
60°C	3·6	4·6	3·7	1·4

(Tests carried out in water)

The above figures apply to monofils of approximately 0·010 in diam which are commercially available. It will be appreciated that higher tenacities can be readily achieved. In the case of such monofils, other considerations, e.g., stiffness, susceptibility to fibrillation, give rise to problems during processing which have not yet been finally overcome.

(c) Knot tenacities

These are to a large extent dependent upon the tenacity/extensibility relationship as determined during spinning of the monofilaments. As the extensibility decreases, the monofilaments become more brittle to a point beyond which the increased tenacity obtained by extra stretching is more than offset by the consequent reduction in knot strength. (Fig. 3 (Lonsdale 1957).)

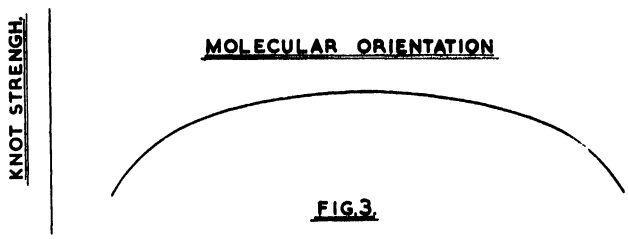

FIG.3.

(d) Load-bearing characteristics

These are best considered in relation to the load/extension curves (Fig. 1). From experiments, it appears that a load of up to 2 g/den is applied to monofilaments during normal trawling operations and an idea of the amount of extensibility at such loads can be obtained from these curves.

There is also the effect of creep under continuous loading to be considered. This varies between types of fibre and also quite substantially between grades of polymers produced by manufacturers. Some monofilaments are criticised on account of creep and Table III shows test results obtained recently for the various monofilaments (outlined in Table II) when subjected to continuous loadings. Fig. 4 shows the time scale which coincides approximately with a normal trawling cycle of operation.

(e) Elastic recovery

Extensibility at working loads is largely recoverable in the case of most synthetic fibres. The monofilaments considered in Fig. 4 were used in illustration of this property (Fig. 5).

(f) Impact strength

This is the amount of energy necessary to rupture the yarns. Tests were carried out on a ballistic tester at 20°C and 65 per cent R.H. as shown in Table III thus:

ergs/g		g.cm/cm.den
$2{\cdot}7 \times 10^8$	'Courlene X3'	3·0
$3{\cdot}1 \times 10^8$	Polypropylene	3·5
$4{\cdot}2 \times 10^8$	Nylon	4·7
$1{\cdot}2 \times 10^8$	Polyvinylidene chloride	1·4

Stiffness or flexibility

This is important when considering the winding or processing of monofilaments. Recovery from creasing is perhaps the best means of comparison and relative values obtained on the 0·010 in diam monofils under consideration are as follows in Table IV:

'Courlene X3'	28
Polypropylene	72
Nylon	102
Polyvinylidene chloride	124

From this table, polyvinylidene chloride might be considered to be the most difficult monofilament to process but the bending modulus (resistance to bending) for this monofilament is low compared with the others.

The crystallinity of fibres is also of importance with regard to recovery from deformation. Table V (Nichols 1954 and others), gives an indication of values for normal monofilaments. In general, the high crystallinity is associated with less recovery from large bending deformations:

'Courlene X3'	80%
Polypropylene	55%
Nylon	50%
Polyvinylidene chloride	70%

Knot stability

The main properties which determine the ease of knotting are stiffness, diameter and shape of cross-section. The crystallinity gives a guide to whether the monofilaments, once knotted, will tend to become loose. From these considerations it will be appreciated that polyethylene has advantages in this respect.

With nylon, the use of double knots, or heat-setting of knots, is commonly practised to overcome deficiencies in knot stability.

Laboratory tests have not shown rectangular cross-sections to be beneficial unless the width: depth axis ratio is at least 10 : 1.

Monofilaments which are substantially round in cross-section, but having a serrated outline, have also proved disappointing from a knot stability point of view.

Abrasion resistance

The results of abrasion resistance testing are known to be unreliable when relating them to actual usage and technologists have long been reluctant to be definite on this subject. A large variety of tests has been devised over the years and, for comparison, we quote results in Table VI obtained by a reciprocating motion of the yarn under 500 g load, across a shot-blasted 'Dural' cylinder of $3\frac{1}{8}$ in diam.

		Arbitrary units
'Courlene X3'	(·009 in diam)	54
Polypropylene	(·011 in diam)	59
Nylon	(·010 in diam)	124
Polyvinylidene chloride	(·011 in diam)	24
830 den nylon multi-filament yarn	(2 tpi)	10

The same tests carried out in water showed the polyvinylidene chloride monofils to be almost the equal of the nylon monofils.

These results help to illustrate the effect of denier/filament, although multifilament yarns can be much improved by judicious use of twist. Twines made from monofilaments generally require less twist than comparable twines made from multifilament yarns, thereby avoiding loss of strength due to overtwisting.

The twist used in the make up of the twine has a direct bearing on abrasion resistance, and a point occurs where twine strength is adversely affected as twist increases (Fig. 6 (Shimozaki 1957)).

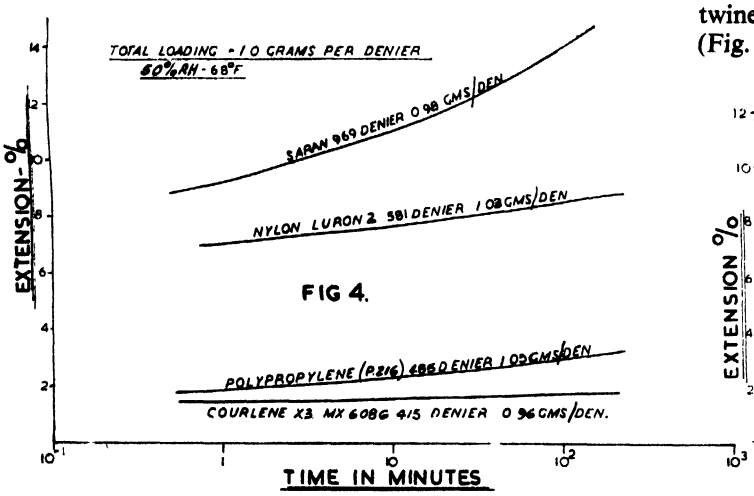

FIG 4.

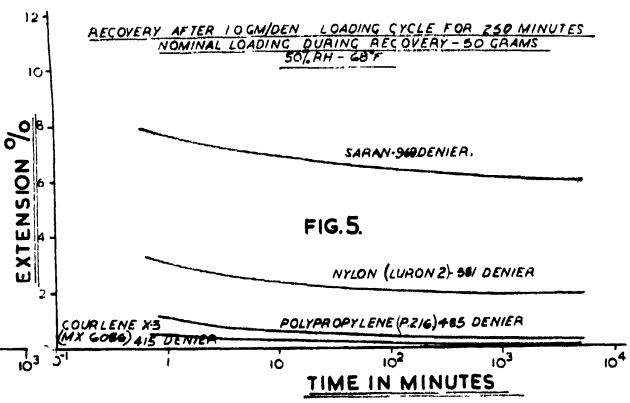

FIG. 5.

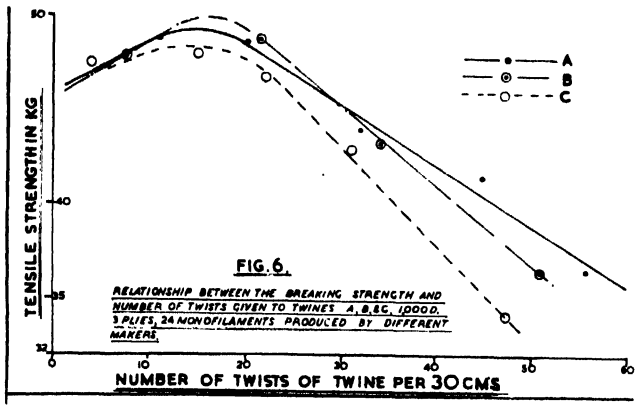

FIG. 6.

RELATIONSHIP BETWEEN THE BREAKING STRENGTH AND NUMBER OF TWISTS GIVEN TO TWINES A, B & C, 1000D, 3 PLIES, 24 MONOFILAMENTS PRODUCED BY DIFFERENT MAKERS.

Over the past few years, we have carried out many practical trials on abrasion resistance, incorporating varying diameters and cross-sections. The results, influenced by other considerations, have in general borne out the textile fibre producer's well-known fact, i.e., the coarser the fibre, the better the abrasion resistance.

Resistance to drag

There has been evidence in the past (Schärfe 1957) that nets made from continuous filament yarns offer approximately six per cent less resistance to towing than comparable manila nets, due to the smoother surface of the twine and also to the fact that a thinner twine could be used. Monofilament twines could be considered even better than multifilament twines due to the lower number of fibres in the twine. Both these types of twine appear to possess the same advantages over natural twines, and trawler owners have confirmed a five per cent fuel saving when changing over from natural fibre nets to 'Courlene' nets over a trial period of several months.

Rot-proof characteristics

Synthetic monofilaments have excellent resistance to sea water. Nylon absorbs some water, with consequent swelling of the fibre and reduction in breaking load when wet (Lonsdale 1957).

It is now common practice not to dry synthetic nets. Preservatives are also regarded as unnecessary unless used to aid knot stability or abrasion resistance. We have had experience of polyethylene nets which have lost none of their properties after immersion in sea water for one year.

Resistance to sunlight

This can vary between different families of polymers and similar polymers made by different manufacturers. The thicker the monofilament the twine or the rope the better, due to greater resistance in depth to penetration by ultra-violet rays. Dark colours are helpful in lessening damage by sunlight. The yarn producer also has access to a wide range of additives (anti-oxidants), some of which may be usefully incorporated.

Test sites are located all over the world for comparison of outdoor tests and laboratory tests. Polyethylene has been developed to the point where it can safely be used outdoors in temperate climates for many years. A recent comparison of monofilaments is given below:

	% breaking load retained	% extensibility retained
Polyvinylidene chloride (clear yarn ·011 in diam)	76	89
Polypropylene (clear yarn ·0075 in diam)	43	48
Nylon (clear yarn ·0075 in diam)	79	80
'Courlene X3' (clear yarn ·0075 in diam)	90	86

Use of monofilaments

Reference to the physical properties described will facilitate an appreciation of the following end uses.

Polypropylene monofilaments are not yet in widespread use for nets. The monofilaments are stiffer and more difficult to process when making twines or braiding into nets. Ways of overcoming this problem are:

(a) The use of finer monofilaments.
(b) Applying less stretch in spinning, which results in monofilaments which are more manageable but lower in strength.
(c) Variation of cross-section.

All these approaches have certain disadvantages in economy, strength, or abrasion resistance. The developments over the next few years will be interesting.

Netting

Where first-class durability and abrasion resistance is required, stout monofilaments have been proved extremely suitable. Polyolefin monofilaments, because of their low specific gravity, tend to remain clear of the sea bed, thus avoiding excessive abrasion, whilst the mouth of the trawl can be maintained in the correct position with fewer floats.

Danish seine nets.—One of the earliest successes occurred in this type of fishing, principally in Scotland. Within a very short space of time penetration was high, and today more than 90 per cent of these nets are made from polyethylene. The material technically was found to be excellent and the economics decidedly favourable. A service life of several years is not uncommon.

Wing trawls.—As with Danish seine nets, a very large number of monofilament wing trawls is now in use and these are universally accepted as an economic replacement for natural fibres.

Midwater trawls.—In this area of fishing, which is largely at an experimental stage in the United Kingdom, a number of nets has been made from both multifilament and monofilament yarns. All have been successful whilst the type most likely to be used will be the net providing minimum drag for a given strength.

Deep-sea trawls.—Deep-sea trawl fishing offers perhaps the best potential in terms of fibre usage and the

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Nylon Monofilament in the Viet-Nam Fisheries

Abstract
Viet-Namese fishermen have for centuries used different types of gear on the many fishing grounds surrounding the peninsula. Different types of gillnets constitute the main equipment used and, while these have varied little in design, the fishermen have over recent years adopted the use of synthetic materials. The Viet-Nam Fisheries Directorate introduced multifilaments to the fishermen, who, of their own accord, changed over to monofilament for the construction of their nets. Some of the advantages attributed by the fishermen to nylon monofilament nets are: they do not retain spiny shells (*limilus sp.*) and other impurities drifting around in the water, and easier to work; spiny fish especially are easier to remove from the nets; less damage is caused when the nets become snagged on reefs; the meshes are largely open for true gilling nets; for daylight fishing the nylon monofilament is nearly invisible, while multifilaments give a bright reflection. Monofilaments are furthermore cheaper by half. Disadvantages as compared with multifilament are: that the netting is more bulky and tends to blow around during operations; monofilament is more difficult to braid and tends to become stiff at low temperatures: Of an estimated 11,000 gillnets in operation in the Viet-Nam fisheries, about 8,000 are of monofilament as compared with only 160 multifilament nets.

L'Utilisation de monofilaments de nylon dans les pêches Vietnamiennes

Résumé
Les pêcheurs Vietnamiens ont depuis des siècles utilisé divers types d'engins pour opérer sur les différents lieux de pêche situés tout autour de la péninsule. Les différents types de filets maillants constituant l'équipement principal ont peu varié dans leur construction et, au cours des dernières années les pêcheurs ont utilisé des matériaux synthétiques. L'Office des Pêches Vietnamien a introduit les fils synthétiques multifilaments mais les pêcheurs, de leur propre initiative les ont remplacés par des monofilaments pour la construction de leurs filets. Quelques uns des avantages attribués par les pêcheurs aux filets en nylon monofilament sont les suivants: ils ne retiennent pas les impuretés dérivant dans l'eau et sont plus faciles à travailler; les poissons épineux en particulier, sont plus faciles à dégager des filets; les filets sont moins endommagés lorsqu'ils sont accrochés dans les coraux; l'ouverture des mailles

Tran-Van-Tri

by
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and
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Fisheries Directorate, Viet-Nam

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United Kingdom industry provides good facilities for experimentation. Penetration, however, has been slow, not because of technical inferiority or unsuitability, but due to the unfavourable economic parity ratio arising from the high incidence of gear loss. Modern detection methods are already helping to minimise this.

The rate of usage will rapidly increase as the effects of the improved economic life are realised and particularly now that a replacement net in synthetics can be purchased at no more than twice the traditional net.

Shrimp nets and lobster pots.—The ease of cleaning and long life are particular features of monofilament nets for this type of fishing.

Salmon trapnets.—Cleanliness, rot-proof characteristics and long life are important. Protection against scavengers, such as seals, has been afforded by monofilament nets compared with cotton nets.

Longline fishing.—Monofilament lines and snoods are renowned for their relative freedom from tangling and cleanliness in use. The floating characteristics of polyolefin monofilaments ensure that snoods tend to rise in the water and be clear of the sea bed.

Ropes

The last five years have seen a progressive attack on the whole field of activity where hard fibres have held the market so completely for so long. Whilst the monofilaments had much to commend them at the start of the development phase, knowledge of the possible polymer deficiencies manifest in fibres compelled caution. If a filament were subject to high stress at an elevated temperature for a long period of time, it was known that an irrecoverable yield would result. The question was, therefore, do such combinations occur in practice? A comprehensive testing programme was necessary to test this and other possible deficiencies in the material, covering end uses from large marine mooring hawsers to longlines in Norway. These field trawls have shown that such a combination of conditions rarely happens in practice.

For example, $6\frac{1}{2}$ in circ-three strand polyethylene ropes have stood the test of two years continued use as first ropes ashore on a 20,000-ton tanker, and are still in use. By comparison, a hard fibre rope is normally replaced every nine to twelve months.

It is evident that the fishing industry provides an opportunity for the widespread usage of polyolefin monofilaments, since the question of temperature sensitivity does not arise. A wide range of end use applications has confirmed the basic suitability of these materials.

Quarter ropes and mooring ropes for all types of trawlers, together with headropes for seine nets, are all in regular use. More recently, successful trials have been carried out with weighted polyethylene ropes for use as seine warps.

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est plus constante; pour la pêche pendant la journée, le nylon monofilament est presque invisible tandis que les multifilaments donnent des reflets brillants. De plus les monofilaments sont de moitié moins chers. Par contre, comparés à ceux en multifilaments, les filets monofilaments sont plus volumineux et susceptibles d'être gonflés et chassés par le vent pendant les opérations; le monofilament est plus difficile à travailler et devient raide à basse température. Des 11.000 filets maillants en opération dans les pêcheries vietnamiennes, environ 8.000 sont en monofilaments et seulement 160 en multifilaments.

El empleo de monofilamentos de nylon en las pesquerías de Viet-Nam

Extracto

Los pescadores vietnameses emplean desde hace siglos diversas clases de artes en los muchos caladeros que rodean la peninsula. El equipo principal lo constituyen diversas clases de redes de enmalle y aunque sus formas han cambiado muy poco, en los últimos años se emplean materiales sintéticos. La Dirección de Pesca de Vietnam les ofreció multifilamentos, pero los pescadores prefieren emplear monofilamentos para construir sus redes, porque entre las ventajas que les atribuyen están: menos peligro de enredarse y manipulación más fácil; es más sencillo desenmallar los peces, particularmente los de aletas duras; menos averías cuando las redes se enganchan en las rocas; la malla es más constante para los artes verdaderamente agalleros; los monofilamentos de nylon son casi invisibles de día, en tanto que los multifilamentos dan reflejos brillantes; los monofilamentos cuestan la mitad, aproximadamente. Los inconvenientes son: las redes son más voluminosas; los monofilamentos son más difíciles de trenzar y se endurecen cuando la temperatura es baja. De las 11.000 redes de enmalle usadas en Viet-Nam, unas 8.000 son de monofilamentos y sólo unas 160 de multifilamentos.

RICE and fish are basic foods in Southern Viet-Nam. Along its 1,800 km of coastline a great variety of gears are used because of the many different fishing conditions and fish species.

Beach seines, fish traps, pair trawls, gillnets of different operational types, and the usual variety of hookline gear have developed. Of these gears, gillnets, and especially driftnets, are perhaps the most important. Whilst traditionally made of ramie and cotton, synthetic materials have been in use for some time.

In 1958 the Fisheries Directorate imported some multifilament nylon gillnets of three inches (four fingers) stretched mesh size for use on the east coast where similar cotton and ramie nets were used. The fishermen at first were very reluctant to use them. However, a few fishermen did insert a few such nets in their own string of nets, to compare the catch efficiency. The excellent results completely broke down the fishermen's prejudice—catches were up to 300 per cent higher than in traditional nets. Demands for synthetic twines quickly surpassed the supply available.

Nylon monofilament had for some time been in use for the construction of snoods in different hook gears as well as for handlines. Some fishermen, unable to obtain multifilament nylon for gillnets, turned to the light monofilament, being convinced that even monofilament nylon was better than the natural fibre previously used.

From the beginning, these monofilament nets obtained at least as good results as the multifilament nets and, by introducing small adjustments to mesh size and hanging, the fishermen very soon obtained even better results with monofilament nets than with multifilament nets. Thereafter the demand for monofilament of various diameters greatly increased. The nets are used with local-made plastic floats and tight-fitting leads; both are available in several sizes to fit the mesh size and type of operation (Fig. 1).

Fig. 1. Monofilament net with plastic floats and lead sinkers.

The Directorate of Fisheries has to date not yet conducted suitable comparative fishing experiments to ascertain whether the monofilament nets do in fact catch more. The fishermen on the east coast are convinced that these nets have a higher catch efficiency because of their transparency. This, on the other hand, does not justify the preference for monofilament of fishermen operating on the west coast where the water is very turbid.

Visibility of monofilament nylon nets is not the only feature governing the preference of fishermen, and it may be useful to record some of the advantages and disadvantages attributed by fishermen to these materials.

Advantages of monofilament nets

(a) The twine is relatively stiff and very smooth and does not retain spiny shells (*limilus sp.*) and other impurities drifting around in the water. Multifilament, owing to its high flexibility and very fine denier, picks up such trash very easily so that cleaning nets is much more difficult.

(b) Gilled and entangled fish, especially spiny fish, appear to be much more quickly released from monofilament than from multifilament nets.

(c) Some of the fishing is done near coral reefs and, when the nets become snagged on coral, monofilament nets are released much more quickly and with less damage.

(d) The fishermen believe that, owing to the stiffness of the yarn, the meshes remain largely open.

(e) The transparency of monofilament nets reduces their visibility in the water, particularly in daytime, whereas multifilament nets give a brilliant reflection which may scare the fish away. This would seem to be especially the case round the edges of tears, so that the hole in the net is very visible to the fish. During daytime monofilament gillnet fishing is more efficient than multifilament nylon nets. However, the fishermen remark that multifilament nets are particularly good in catching the *Stromateus sp.* as the nets entangle the fishes.

(f) The monofilament nets have been found to catch at least as much fish as the multifilament ones and are cheaper by half. The reason for the lower cost of monofilament twines is that multifilament must still be imported whereas nylon monofilaments are manufactured in Saigon by six local firms.

Disadvantages of monofilament twines

(a) One disadvantage of monofilament nets is bulkiness. Fishermen combat this by forcing the netting in the forward fish-hold and weighting it down (Fig. 2).

Fig. 2. Storage of nets on board.

(b) The netting during shooting and hauling tends to blow around more than the multifilament nets and this can slow down the operation. This has largely been overcome by adapting the shooting and hauling techniques to this condition.

(c) Monofilament does not braid as easily as multifilament because of its stiffness; on the other hand, no serious difficulty has been experienced as regards

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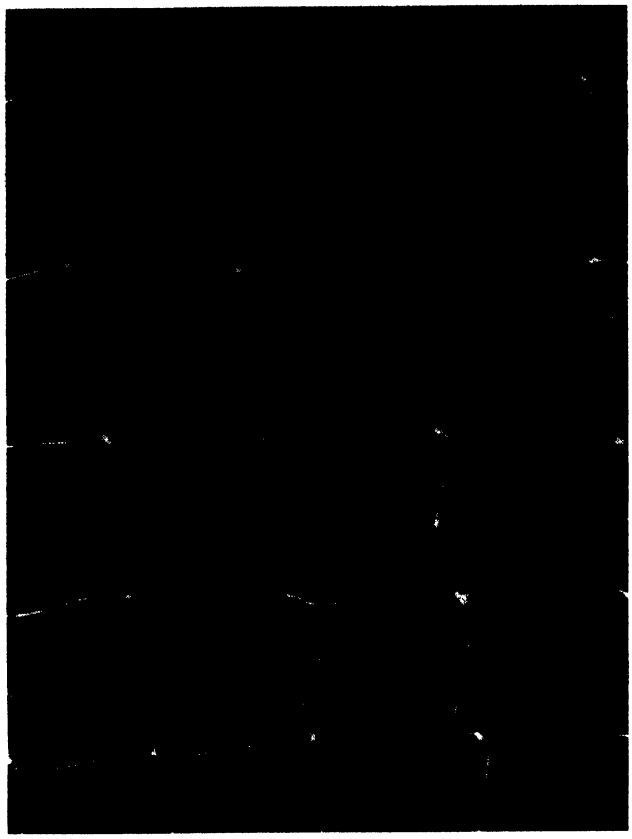

Fig. 3. Joining of twine between knots when mending.

Fig. 4. Mending the nets.

Monofilament Gillnets in Freshwater Experiment and Practice

Abstract

Experimental studies on the comparative importance of the properties of gillnet materials have shown that in clear water the visibility is the most important factor. Net materials should have low visibility, giving little or no contrast to the background, and be transparent; synthetic monofilaments yield the best catches. The softness of the netting was found to be of only secondary importance. The diameter of the netting material influences the catch efficiency only inasmuch as thicker twines are more visible than thinner ones. The elasticity appears to have hardly any influence on the size of the fish caught while the visibility does appear to have a selective effect. The breaking strength is only of importance for large fish and operational considerations, because small fish such as perch and roach cannot produce the force required to damage commercial gillnets. The hanging determines the shape of the meshes, the distribution of the forces in the net and the looseness in the netting. The framing lines may influence the catch efficiency by their visibility. The amount of floats and sinkers depends on the operational conditions, the current and the amount of tension required in the netting.

Filets maillants de monofilament dans la pêche continentale

Résumé

Des études expérimentales sur l'importance comparative des propriétés des matériaux pour filets maillants, ont montré que la visibilité est le facteur le plus important pour la pêche en eaux claires. Les matériaux de filets doivent avoir une faible visibilité contrastant peu ou pas tout avec le milieu et doivent être transparents; dans ces conditions, les monofilaments synthétiques produisent les meilleures captures. La mollesse des filets est d'importance secondaire. Le diamètre du matériel des filets a une influence sur l'efficacité de capture seulement dans la mesure où les fils épais sont plus visibles que les fils fins. L'élesticité semble avoir peu d'influence sur la grandeur des poissons capturés tandis que la visibilité a un remarquable effet sélectif. La force de rupture n'est importante que pour les grands poissons et pour des considérations d'opération puisque les petits poissons comme la perche et le gardon n'ont pas assez de force pour en ommager les filets commerciaux. Le taux d'assemblage détermine la forme des mailles, la distribution des forces dans le filet et le relàchement du filet. La visibilité des lignes encadrantes peut influer sur l'efficacité de la capture. Le nombre de flotteurs et le poids dépendent des conditions d'opérations, du courant et de la tension nécessaire dans le filet.

by

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Redes de monofilamentos para la pesca de enmalle en agua dulce

Extracto

Los estudios experimentales de la importancia relativa de las propiedades de los materiales para la fabricación de redes de enmalle han demostrado que en agua clara la visibilidad es el factor más importante. Los materiales para redes deben ser casi invisibles, crear muy poco o ningún contraste con el fondo y ser transparentes. Los monofilamentos sintéticos dan las mayores capturas. Se demostró que sólo tenía importancia secundria que el material fuera blando. El diámetro de los hilos sólo influye en el rendimiento de la pesca en que los de mayor diámetro son más visibles que los de menor diámetro. Parece ser que la elasticidad apenas tiene efecto en la talla de los peces capturados y que la visibilidad tiene un efecto selectivo. La resistencia a la rotura sólo tiene importancia para los peces peces grandes y en lo que a la manipulación se refiere, ya que peces pequeños como la carpa no tienen la fuerza necesaria para averiar las redes de enmalle comerciales. La manera de armar, es decir, los metros de paño por metros de relinga, determina la forma de las mallas, la distribución de las fuerzas en la red y si los paños quedan flojos. Las relingas de las cuarteladas pueden influir en el rendimiento de pesca a causa de su visibilidad. La cantidad de flotadores y plomos depende de las condiciones de trabajo, la corriente y la intensidad de la tensión necesaria en los paños.

IN spite of relatively high cost, gillnets are of great importance. By adopting proper mesh size only fish of the desired range are caught, while undersized fish

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knot slippage as the fishermen make the nets with double knots and also mend between knots as shown in Figs. 3 and 4. The great majority of nets in Viet-Nam are braided by hand by the fishermen and in practice it has been found that this cannot be done well with monofilaments thicker than 0.90mm diam.

Monofilament seems to be more sensitive to the lower temperatures and nets made from this material used in the cooler regions and during the winter season tend to become stiff thereby becoming even more bulky out of the water and less flexible during operations. Water temperatures vary from 22°C to 29°C the year round.

Future of monofilament gillnets

Use of nylon monofilament for gillnets is progressing very rapidly in Viet-Nam. No accurate figures of the total nets in use are available but a general estimate shows that some 11,000 gillnets are in use. The number of monofilament and multifilament synthetic fibre nets in use over the period 1958/62 is given in the table:

	1958	1959	1960	1961	1962
Multifilament gillnets	5	50	80	140	160
Monofilament gillnets	2	30	1000	3000	8000

Gillnet fishermen in Viet-Nam normally work on a share-on-catch basis and the popularity of monofilament nets is such that the best fishermen engage themselves only with owners of motorised boats using monofilament gillnets. The sail boats, many of which still use natural fibres, are experiencing difficulties in obtaining good crews and, furthermore, operate at economic disadvantage to motorised craft.

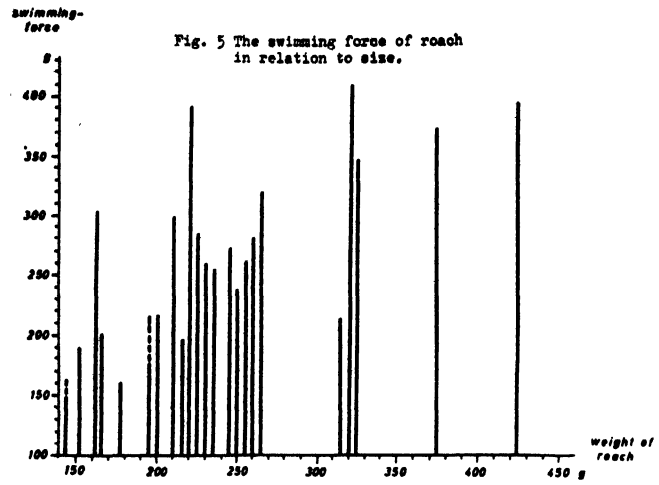

Fig. 5 The swimming force of roach in relation to size.

A greater number of older and larger fish seems to be caught with low visibility nets, indicating a more careful approach towards gillnets than younger specimens. This influence of the visibility on size of fish, however, varies according to the fish species; it appears stronger for perch than roach. The elasticity of the net materials is of importance for the gilling process and for retaining gilled fish in the meshes, but this has hardly been studied so far.

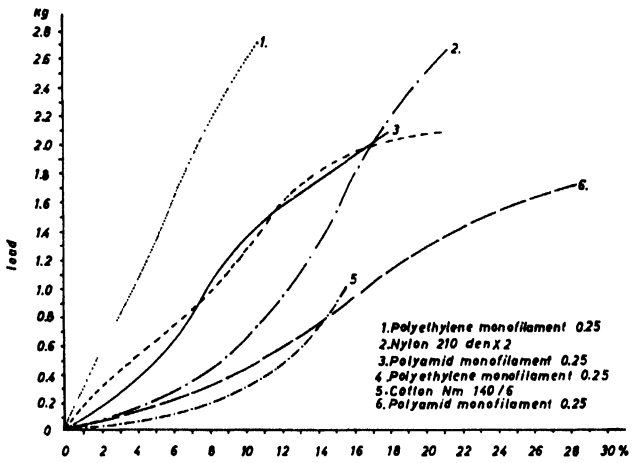

Fig. 6 Load-elongation curves of net twines of 0.25 mm diameter.

Breaking strength—Because of the fineness of the net materials, breaking strength is of high importance. Nowadays most gillnets are made of machine-braided netting, which process already requires a certain minimum breaking strength and the strength required for handling and operation must also be considered. Selection of net material is, therefore, a compromise between the higher breaking strength needed for lengthy trouble-free operation and the most desirable diameter for minimum visibility. The strength of the fish only needs consideration where it concerns large-sized species. High tenacity materials, therefore, are essential for gillnets.

Constructional properties of gillnets which influence the catch efficiency are: mesh size, hanging, framing lines, floats and sinkers and height of the net.

Mesh size—With true gilling nets the mesh size delimits the size of the fish caught so that such gillnets are very selective, catching only fish of a distinct size. Smaller and larger fish may, however, be entangled if the net is loosely hung.[1 30] This selectivity of gillnets enables the taking of only those specimens from fish stock which, by their size, represent a good market value and are mature so that their loss is of no serious consequence for the preservation of the stock.

The selection of the optimum mesh size requires a sound knowledge of the composition of the fish stock and must be determined for each water body in accordance with that knowledge and their needs.

Hanging—While hanging determines the shape of the meshes and the distribution of the forces in the net, it may also influence the selectivity.[1] It would seem that for fish with a narrow and high cross-section the mesh shape should be stretched in vertical direction while for flatfish the meshes should be stretched horizontally; the latter, however, gives very tight hanging. The hanging defines the looseness of the netting and very often it is desirable to have loose netting so that fish can be entangled as well as gilled. This looseness can also be obtained by attaching connecting twines between floatline and leadline which prevent the netting from stretching fully.

Framing lines—Gillnets used in freshwater fishing are normally provided with a complete frame of lines, bulky enough to handle and strong enough to withstand shooting and hauling.

The visibility of the framing lines may have an effect on the catch efficiency.[8 26 30] Experiments with nets framed with differently coloured lines showed that those with green lines caught 61 perch and 153 roach while the white-lined nets caught under the same conditions 22 perch and 37 roach respectively.

Floats and sinkers—Floats and sinkers, to achieve the desired vertical position of the net in the water, must be distributed uniformly. A large number of small floats is usually preferable to a small number of large floats and for submerged nets the total buoyancy must not produce undue tension[1] in the netting.

The shape and colour of the floats should not contrast unduly with the water or background, otherwise they may affect the catching efficiency in the same way as the framing lines.

Net height—Bottom-set gillnets in inland fishing are usually of small height and experiments showed that an increase beyond 1·0 to 1·5 m does not normally result in better catches.

Duration of fishing—Catch efficiency of gillnets decreases when the fishing time is increased and also with an increase in the number of fish gilled. In experiments in the Great Slave Lake[17] it was found that, by extending the duration of a set from 24 to 48 hours, the catch

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Etudes sur le Freinage et L'Usure des Fils de Pêche

Résumé
La fabrique de fils et cordes "Cousin Frères", France, procède à des études constantes pour améliorer ses produits. Lorsque les résultats obtenus sont d'une importance technologique générale, elle consulte des Instituts indépendants—en ce cas l'Institut de Mécanique des Fluides de Lille et le Laboratoire Fédéral Suisse de Saint Gall, afin que ceux-ci effectuent des épreuves de contrôle, le résultat est alors porté à la connaissance des pêcheurs, des constructeurs de filets et des clients en général. La présente communication traite de trois de ces essais. Les deux premiers concernent la traînée comparative de fils de filets; au cours de ces essais il a été constaté qu'à une vitesse de trois noeuds, la traînée du coton était supérieure de 50 pour cent à celle du nylon en monofilament continu d'un diamètre équivalent et avait trois fois plus de résistance à la traîne, pour d'égales forces de rupture. Les fils en nylon tressé de même diamètre que les fils en nylon câblé avaient une résistance à la traînée légèrement inférieure. Le troisième essai destiné à éprouver la résistance à l'abrasion des fils a montré que le nylon câblé avait sept fois plus de résistance que le manille et le sisal à sec mais que mouillé, il n'était que très peu supérieur au sisal. D'un autre côté la résistance à l'abrasion du nylon tressé est cinq fois plus grande que celle du nylon câblé et sa résistance à l'abrasion est la même sous les deux conditions. Les fils de nylon tressé ont donc un gros avantage pour la construction des chaluts par suite de leur haute résistance à l'abrasion et leur très basse résistance àl a traînée.

Study on the drag and abrasion of fishing twines

Abstract
The net and rope factory of Cousin Frères, France, carries out continuous studies aimed at improving their products. From time to time when results are obtained which are of general technological importance, independent institutes, in this case, Institute de Mécanique des Fluides de Lille and Laboratoire Fédéral Suisse de Saint Gall, are requested to carry out conclusive tests, the results of which are then brought to the notice of fishermen, net-makers and clients in general. The present paper concerns three tests: the first regarding the comparative drag of twines when made into nets, during which it was found that at three knots the drag of cotton twines was 50 per cent higher than that of nylon continuous multifilament of equivalent diameter, and about three times higher resistance when compared on equal strength basis. Braided nylon twines of comparative diameter offer slightly less resistance than cabled nylon twines. The second experiment on the abrasive resistance of twines showed that cabled nylon had up to seven times higher abrasion resistance than manila and sisal in the dry condition but only slightly more resistance than sisal in the wet condition. On the other hand, the abrasive resistance of braided nylon was five times higher than that of cabled nylon, and its resistance is almost the same in dry and wet condition. Braided nylon twines have, therefore, great advantages for use in trawls because of high abrasive resistance and low drag.

by
Maurice Bombeke

Establissements Cousin Frères

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increased only very little. Similar results were obtained in Northern German Lakes. Gillnets should be lifted and cleared at least once a day and even at much shorter intervals under certain conditions, such as in the tropics or where predators are abundant.

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Estudios de la resistencia y desgaste de hilos para redes

Extracto
La fábrica de redes y cordelería Cousin Frères, Francia, realiza continuamente estudios para mejorar sus productos y de vez en cuando, los resultados obtenidos son de importancia tecnológica general, solicita de institutos independientes, en este caso el Institut de Mécanique des Fluides de Lila y el Laboratoire Fédérale Suisse de Saint Galle que realicen ensayos definitivos cuyos resultados se comunican a pescadores, fabricantes de redes y clientela general. Esta ponencia alude a tres ensayos: el primero sobre la resistencia comparativa de hilos cuando se hacen las redes. Durante éste se observó que a tres nudos de velocidad, la resistencia de los hilos de algodón es un 50 por ciento mayor que la de los filamentos continuos de nylon del mismo diámetro y unas tres veces mayor a igualdad de robustez. Los hilos de nylon trenzados ofrecen algo menos resistencia que los torcidos de diámetro análogo. El segundo experimento, sobre la resistencia al desgaste, demostró que el nylon torcido ofrecía seite veces más resistencia al desgaste que el abacá de Manila y el sisal estando secos, pero sólo un poco más que el sisal estando húmedo. Por otro lado, la resistancia al desgaste del nylon trenzado es cinco veces mayor que la del torcido y la resistencia a la tracción casi igual estando seco que húmedo. Se deduce de ello que los hilos de nylon trenzado ofrecen grandes ventajas en los artes de arrastre por su gran resistencia al desgaste y pequena a la tracción.

DANS le but de perfectionner leurs produits, les établissements Cousin Frères de Wervicq-Sud, France, font constamrhent des études sur les matériaux utilisés et les méthodes de fabrication. De temps en temps lorsque des résultats intéressants sont obtenus, des épreuves concluantes sont exécutées dans des conditions contrôlées par les Instituts reconnus; les résultats de telles épreuves sont alors portés à la connaissance des pêcheurs, des fabricants de filets et des clients en général La présente communication traite de trois de cesépreuves.

Mesure de la traînée de fils de pêche

Le but de cette étude faite par l'Institut Mécanique de Lille, était de connaître la force à employer pour tracter deux fils câblés de même force à la rupture: l'un en coton et l'autre en nylon.

Les fils à essayer étaient de cinq types:

(a) fil de coton, diamètre approximatif 1 mm
(b) fil de coton, diamètre approximatif 1·8 mm
(c) fil de nylon, diamètre approximatif 0·9 mm, cablé
(d) fil de nylon, diamètre approximatif 1 mm, tressé
(e) fil de nylon, diamètre approximatif 1 mm, tressé Wercord.

Pour les essais, chaque type de fil est monté sur un cadre en bois profilé de une mètre de coté, fixé rigidement aux mâts verticaux d'une balance aérodynamique.

Les fils sont montés verticalement et horizontalement, de façon à obtenir des mailles carrées de 20 mm de côté environ. Il y a ainsi, pour chaque type de fil 98 mètres de fil essayé.

Les essais ont été effectués dans la Soufflerie Horizontale de l'Institut de Mécanique des Fluides de Lille, de diamètre 2·40 mètres en veine guidée.

Traînée des fils dans l'air

Les résultats des essais effectués en soufflerie sont consignés dans les tableaux suivants; les colonnes A donnent la pression dynamique en mm eau; les colonnes B donnent l'effort de traînée en kg (Tableau I).

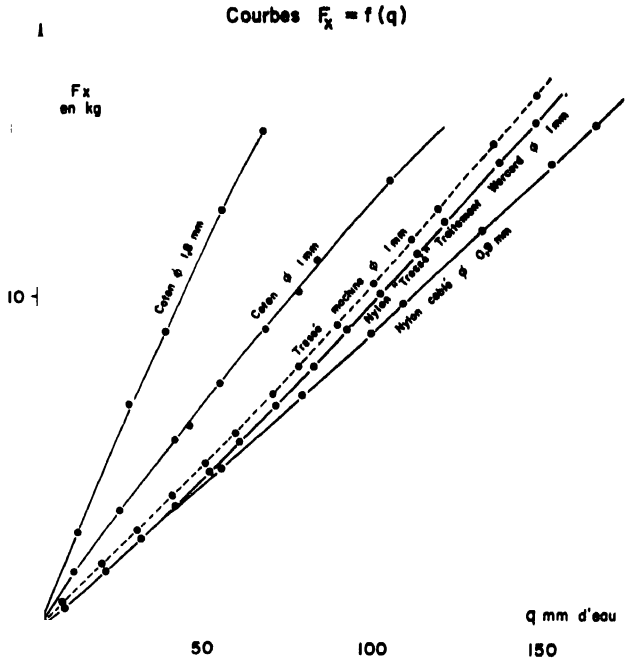

Planche 1. Traînée des fils de pêche dans l'air.

Traînée des fils dans l'eau de mer

A partir des essais effectués dans l'air, nous calculons l'effort de traînée s'exerçant dans l'eau de mer sur 100 mètres de fil de chaque type, pour des vitesses d'avancement évaluées en noeuds.

Pour un même nombre de Reynolds: $R \frac{V.D.,}{v}$ on détermine d'abord la vitesse du courant d'air correspondant à une vitesse d'avancement dans l'eau. Comme le diamètre D est constant, on doit avoir:

$$\frac{V}{v}\text{ air} = \frac{V}{v}\text{ eau}$$

d'où

$$V\text{ air} = V\text{ eau} \times \frac{v\text{ air}}{v\text{ eau}}$$

Les valeurs de la viscosité cinématique v sont:
Air à 15°: $v = 0{\cdot}15$ stokes
Eau de mer à 4°: $v = 0{\cdot}015$ stokes
Ce qui donne: V (air) = 10 V (eau)

A une vitesse d'avancement dans l'eau de quatre noeuds par exemple, correspond une vitesse du courant d'air de 40 noeuds, soit 20·55 m/sec, qui équivaut à une d'eau.

Pour une vitesse donnée, on écrit ensuite, que les coefficients de traînée dans l'air et dans l'eau sont égaux:

$$\frac{Fx}{\rho_g\ V^2\text{ air}} = \frac{Fx}{\rho_g\ V^2\text{ eau}}$$

Ce qui donne: $Fx\text{ (eau)} = Fx\text{ (air)} \times \frac{\rho\text{ eau}}{\rho\text{ air}} \times \frac{V\text{ eau}^2}{V\text{ air}}$

Les valeurs de la masse spécifique ρ sont:
Air à 15°: $\rho = 1{\cdot}226$ kg/m³
Eau de mer à 4°: $\rho = 1{\cdot}026$ kg/m³

$$\text{d'où: } Fx\ (\text{eau}) = Fx\ (\text{air}) = \frac{1{\cdot}026}{1{\cdot}226} \times \frac{1}{10}^{2}$$

$$= 8{\cdot}37\ Fx\ (\text{air})$$

Dans l'exemple choisi, on lit sur la Pl.2 la valeur Fx (air) correspondant à q=26·4 mm d'eau, soit Fx (air)= 2·350 kg pour le fil tressé nylon traitement Wercord. Pour une vitesse d'avancement dans l'eau de duatre noeuds, on a donc, un effort de traînée:

Fx (eau)=8·37×2·35=19·620 kg

Les traînées ainsi obtenues dans l'eau de mer sont données dans le tableau cidessous, et portées en courbes Pl.2.

Tableau I

Nylon tressé traitement WERCORD de 1 mm		Nylon tressé de 1 mm	
A	B	A	B
7,60	0,695	6,85	0,830
19,30	1,790	18,75	1,915
30,10	2,720	28,90	2,920
40,10	3,650	39,20	3,980
50,30	4,690	49	4,960
59,20	5,580	57,40	5,800
69,25	6,700	67,60	7,020
80,90	7,880	76	7,860
90	8,930	86,20	9,130
99.70	9,980	97,20	10,320
110	11,220	108,10	11,600
118,20	12,100	116,60	12,530
134,20	13,820	132,50	14,400
145	15,050	145	15,850

Coton de 1 mm		Nylon de 0,9 mm		Coton de 1,8 mm	
A	B	A	B	A	B
11,27	1,730	11,45	1,010	12,75	2,980
24,80	3,580	24,60	2,230	28,10	6,595
40,70	5,745	40,30	3,660	38,30	8,800
46,00	6,110	54,30	4,910	55,30	12,490
54,75	7,445	67,50	6,105	66,40	14,825
67,70	9,090	73,80	6,570	82,20	18,225
77,80	10,035	78,50	7,050	98,00	21,625
83,50	11,035	98,09	8,910	109,30	23,940
101,90	13,215	108,00	9,750	122,30	26,660
106,00	13,415	125,40	11,360		
117,70	15,095	132,00	11,960		
126,40	16,155	134,70	12,365		
132,30	16,680	151,40	13,895		
141,50	17,975	164,20	15,110		
154,00	19,375				
165,50	20,775				

TABLEAU II—Effort de traînée en kg sur 100 m de fil

Vitesse	Nylon de 0·9 mm	Coton de 1 mm	Coton de 1·8 mm	Tressé Nylon traitement Wercord de 1 mm	Tressé nylon de 1 mm
1 noeud	1,275	2,00	3,270	1,255	1,420
2 noeuds	5,150	7,80	13,00	5,010	5,520
3 noeuds	11,675	18,00	29,40	11,370	12,530
noeuds	20,700	32,00	52,00	19,650	22,200

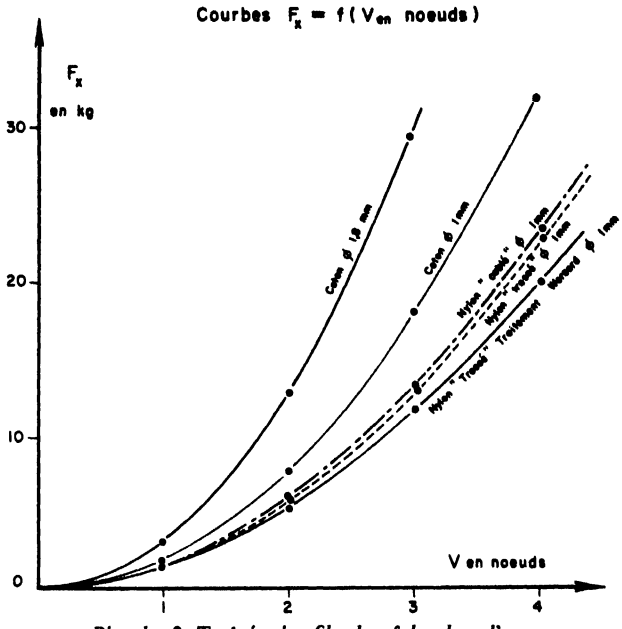

Planche 2. Traînée des fils de pêche dans l'eau.

Remarque

Les caractéristiques des torons qui constituent le fil de nylon "câblé" de diamètre 0·9 mm sont identiques à celles des torons du "tressé machine". La force de traînée étant directement proportionnelle à la surface frontale du fil, on peut, à partir des résultats obtenus pour le 0·9 mm, calculer les efforts de traînée s'exerçant sur le fil de nylon "câblé" de diamètre un mm. Ces résultats portés en courbes à la planche deux sont à l'avantage du nylon "tressé" qui, dans l'eau subit un effort de traînée légèrement inférieur à l'effort que subirait un fil de nylon "câblé" de même diamètre.

L'essentiel de cette étude était de trouver quelle était la différence de traînée existant entre les câblés et les tressés: la conclusion est que la tresse nylon offrant moins de résistance à la traction que le câblé nylon, son emploi est vivement recommandé pour les chaluts pélagiques.

Tenue a l'abrasion des tresses et câblés nylon pour filets de pêche

(Etude faite par le Laboratoire Fédéral Suisse de Saint Gall)

Articles essayés: 1 bobine de tresse en Nylon 4840/3
1 bobine de câblé-Nylon carte Rouge 502-réf. 270
1 pelote de manille trois fils 8/10
1 pelote de sisal trois fils 8/10
1 pelote de ficelle CH-D trois fils 8/10

Conditions d'essai:

Le matériel est climatisé à 65 pour cent d'humidité relative et 20°C.

Mode d'examen:

Des éprouvettes prélevées de chacun des échantillons sont tressées dans une plaque perforée. Les boucles

sortant du côté supérieur sont frottées par l'élément frottant plat de l'appareil Schiefer jusqu'au moment de la destruction de la premiêre boucle. La perte de poids moyenne, calculée par 1,000 tours, est déterminée en même temps. Les deux échantillons de nylon sont pesés après les premiers 2,000 tours, ceux de manille et de ficelle CH-D après les premiers 500 tours et l'échantillon de sisal après les premiers 250 tours.

Afin de déterminer les pertes de poids des éprouvettes mouillées, tressées dans les trous du disque perforé et puis abrasées pour atteindre le nombre de tours indiqué. Ensuite elles sont sèchées, climatisées et pesées.

Résultats:

Les essais ont donné les résultats suivants:

Tableau III RÉSISTANCE A L'ABRASION

	Poids par m courant g.	sec				mouillé			
		Tours d'abrasion moyenne	Coefficient de variation %	Perte de poids moyenne g	Coefficient de variation %	Tours d'abrasion moyenne	Coefficient de variation %	Perte de poids moyenne g	Coefficient de variation %
Tresse nylon 4840/3	3,92	24500	19	0,035	19	23600	20	0,015	26
Câblé nylon Carte Rouge 502, 1/ef. 270	3,92	4600	27	0,027	16	5400	22	0,026	5,2
Manille 3 fils 8/10	3,92	640	21	0,338	6,3	1850	25	0,262	19
Sisal 3 fils 8/10	3,81	650	23	0,376	4,5	7200	43	0,417	15
Ficelle CH-D 3 fils 8/10	4,16	690	13	0,356	9	5100	74	0,546	14

Cette étude démontre la grande résistance à l'usure de la tresse nylon, elle a déterminé l'emploi de la tresse nylon dans la construction, notamment, des chaluts et des grandes seines tournantes.

En France, l'emploi de la tresse nylon pour les chaluts est maintenant général; les chaluts de grande pêche portugais, espagnols et italiens sont également fabriqués avec la tresse nylon.

Discussion: Materials for Lines, Ropes and Monofilaments

Dr. J. Reuter (Netherlands) Rapporteur: Most synthetic fibres are produced by extrusion with orientation or stretching afterwards. As a result of this, textiles, net twines and lines and ropes are often made of the same stretched fibre. It seemed strange that different articles used for different purposes can be made from the same type fibre and still have for different purposes, optimal and good properties.

By experiments, he and C. C. Kloppenburg had tried to find out what fibre type of polyethylene was the best for special purposes—specifically for (a) a strong trawl twine which remained strong when knotted; and (b) a strong rope in the sense of having the highest breaking strength.

Eight different types of monofilaments—based on polyethylene—made respectively out of homopolymer and copolymer (with different orientation) were produced. From all these monofilaments trawl twine was made and tested on breaking strength and knot breaking strength. For both types of polyethylene, the filament that gave the highest breaking strength as twine did not give the highest knot breaking strength.

Ropes were also made from those eight types of filaments in normal and hard lay. As an outcome of these tests it could be said that the type of filament that gave the highest knot breaking strength of trawl twine was the same that gave the highest rope breaking strength; but the highest knot breaking strength of the twine must be made from a different type of filament. This meant that special filaments of polyethylene had to be made for either ropes or nets. For ropes they must be made to give breaking strength and for nets, knot breaking strength.

On knotless nets: It is necessary to point out strongly that there are two types of knotless nets: (a) the Japanese type made by a special way of twisting and (b) the Raschel type made by knitting.

The importance of this last type is pointed out by Mugaas and by Damiani. Mugaas shows that in the last two years in Norway the use of this type of netting has increased from 17 to 200 tons because in the small mesh sizes the knotless nets are 20 to 30 per cent cheaper than the knotted ones. Damiani also shows that in Italy the Raschel machine-made netting is cheaper for smaller mesh sizes but above a certain size the old knotted ones are less expensive.

Dr. von Brandt's paper on testing Raschel knotless nets correlates the properties of this netting with fishing experiments made with the nets, whereas Hamuro deals only with experiments to improve a fishing net by using knotless netting in parts of the trawl. Their work shows that people are seeking to discover for what type of fisheries these knotless nets are better or cheaper than the old ones. It is quite certain that in one or two years' time certain fisheries will change over nearly totally to the knotless type of netting.

Dr. von Brandt showed that the construction of the "twine" and of the joins is rather complicated. But some uniformity will be the result of increased testing by discovering the best methods for these joins. A year ago this mesh strength in the depth direction of the netting was different to that of the length direction. It is in fact already claimed now that the knot strength of this type of netting can be equalled in both directions. Pianaroli states this, too. These differences in mesh strength are admitted by von Brandt and I wonder how much, in consequence of this, new joins with equal strength in both directions, the comparison of knotted to knotless nets based on mesh strength will change. This new basis will also change the weight comparison based on the respective mesh breaking strength. Although these two methods of comparison are somewhat doubtful they do indicate that the knotless nets have a ittle advantage over knotted ones.

The total resistance of this type of netting shows no difference compared with knotted nets of equal mesh-breaking strength. Used in herring gillnets in the North Sear the catching capacity of knotless nets was neither higher no, lower than that of customary knotted gillnets.

It would seem that below a certain mesh size knotless Raschel nets are absolutely cheaper. Due to a new technique of making the joins, the mesh breaking strength in both directions can be made equal and, for that reason, comparison with knotted nets has to be put on a totally new basis. In other words a lot of experimenting and testing has to be done all over again. It is a pity that not much is published in the same way for comparing Japanese twisted knotless nets, especially in relation to physical properties and catching capacities.

On monofilaments: Synthetic fibres for making twines, lines, ropes and nets can be made in different thicknesses with few exceptions. The thicker filaments are often preferred because one thinks that they are more useful and better adapted for certain tasks. The difference of thickness is the

only reason why one fibre is called multifilament and the other monofilament.

Multifilaments are mostly produced in thicknesses of 2 to 25 denier per filament and monofilaments in thicknesses of 50 up to 1,000 denier and even thicker. Even ropes made of filaments 4 mm thick are available.

This difference of filament thickness creates certain properties which make the fibres better adapted for certain work but there are technical reasons which make it sometimes difficult to use monofilaments. Their very thickness creates properties not liked by fishermen.

In their paper Henstead and Ede review these different properties of monofilaments as made of different materials—polyamide and polyolefin. The properties considered, to mention only a few are: (a) tenacity, (b) effect of heat, (c) non tenacity, (d) degree of flexibility, (e) abrasion resistance.

In practice these monofilaments are made and used as a single monofil, as twine or as rope, and are used in different kinds of fisheries. Experience was required to discover in which fisheries a special part of the netting could be made best of monofilaments or multifilament products. There are many fisheries in which monofilaments have played an enormous role, for instance in Viet-Nam. Filaments made there are cheaper than imported multifilament and twine but technical advantages also accounted for their fishermen preferring monofilament nets. These advantages are less fouling, easier to work with, less entangling and catching not less but sometimes more fish than knotted nets. These properties compensated for the bulkiness and other disadvantages of such monofilament nets.

Steinberg lists the properties of monofilament in comparison with other types of nets as (1) visibility, (2) softness, (3) diameter, (4) elasticity and (5) breaking strength.

In this complex matter experiments are needed to find out what is worth while. Monofilaments are used not only as netting material but to produce twine and rope. Mostly such products are made out of olefin monofilaments because of their low specific gravity—I know of only one type of rope made of monofile polyamide.

We stand at the beginning of a period in which fibres and filaments will be produced for special purposes. To adopt monofilaments to the special needs of fishing involves a tremendous amount of practical experiments.

Dr. C. C. Kloppenburg (Netherlands) explained that the colouring pigments had been added to the material tested only for identification purposes and exercised no influence on strength.

Mr. Masao Kobayashi (Japan) expressed pleasure that knotless nets were featured in the Congress: his company had developed twisted knotless nets for many years. They were used for practically all types of fishing in Japan and the annual consumption was some 1,600 tons a year. There had not been sufficient time to study the papers on Raschel nets in comparison with the Japanese twisted nets, but they would do so and submit results. Both the twisted net and the Raschel net were different from the conventional knotted net. Accordingly when such knotless nets were used for purse seines, set nets and trawl nets the way of assembling the knotless netting should differ a little from that of knotted nets.

A suitable method of assembling knotless nets was fully studied in Japan as was shown in Hamuro's paper and it was used in every type of fishing net except a gillnet. His firm belief was that the knotless fishing net was most advantageous.

Dr. von Brandt: I would be very interested to compare types of Japanese and Raschel nets. There are big variations in the different types: both in making and in the joins.

Mr. V. Valdez (Peru), on behalf of Julie Castille, gave details of Peru's purse seine fishery in methods and equipment. Nylon netting, introduced 10 years ago, had undoubtedly contributed greatly to the meteoric growth and development of the industry. Knotless webbing had only recently been effectively introduced through Raschel knotless webbing becoming available at the end of 1961. Some earlier supplies had been too heavily tarred and been awkward to handle and easily breakable. Latest figures showed that 75 purse seines of knotless webbing were in use in a total fleet of 1,200 craft. A survey made in April 1963 by the Marine Resources Research Institute listed these advantages: (1) lower price because of lesser weight, (2) non-tangling of baby fish making operations easier, (3) less friction on the boat and bottom during hauling, thus promoting durability. A company had been formed and was beginning large-scale manufacture of knotless anchovetta nets in a factory containing ten Raschel machines of 960 mesh width. It was believed development in use would exceed Norway's growth and sales in excess of 400 tons were anticipated for 1964. This local manufacture was likely to preclude overseas importation.

Mr. D. L. Worsfield (UK): We have a method which we find very useful for comparison purposes between knotted and knotless nets. If you take the ratio of the wet mesh-strength to the weight of a given area of netting, say 1,000,000 meshes (1,000 by 1,000 square), this can be used for both knotted and knotless nets and this allows for the amount of twine used in the knot or in the junction of the net. If this—parameter K, we call it—1 over K, is plotted against the mesh size you can find the break-even point as far as the strength is concerned, for knotted as compared with knotless netting. Then, by allowing for production costs, this should be very useful for finding when knotless nets can replace knotted netting.

Mr. P. Lusyne pointed out that there were at least four different types of Raschel netting and they should know more about the joins and also more about the strains of the legs of the meshes themselves. Whenever they had mesh breaks it would be useful to know whether they were in the knot or in the legs of the mesh. It would be helpful also to have some project for finding which types of knot or netting gave the greater strength and the greater elasticity. Another point of interest was the breaking strength according to the direction of the pull. Much depended here on the type of connection between each mesh and they needed to know the different effects of the inner lines crossing or weaving.

Arising from a query from Mr. M. Praet as to the meaning of the terms "normal, special and super" in Dr. von Brandt's paper on testing Raschel nets, Dr. von Brandt explained that they had been adopted instead of (a), (b), (c) simply to distinguish three different constructions of material so that they could see what happened.

Mr. Helmut Panzer (Germany) supplier of the material gave a technical explanation of their choice of three types of typical Raschel nets which were already on the market. The most interesting point was the join (see Fig. 4 in Dr. von Brandt's paper this section).

Mr. Kristjonsson: Should the term "monofilament" not be reserved for one filament used alone and not for two or more filaments twisted together? They should talk about heavy multifilaments when using heavy denier for making ropes as is now being done.

Dr. Reuter, summing up, said he considered the most important subject was testing; the testing of knotted net in relation to knotless netting. He had tried to get from a factory making Raschel nets a certain twine but as yet had not received it. A new system had been devised and people wished to keep it for themselves. It was impossible to repair knotless nets without using knots. Knots had to be used. As to terminology, any change would be difficult because custom was involved.

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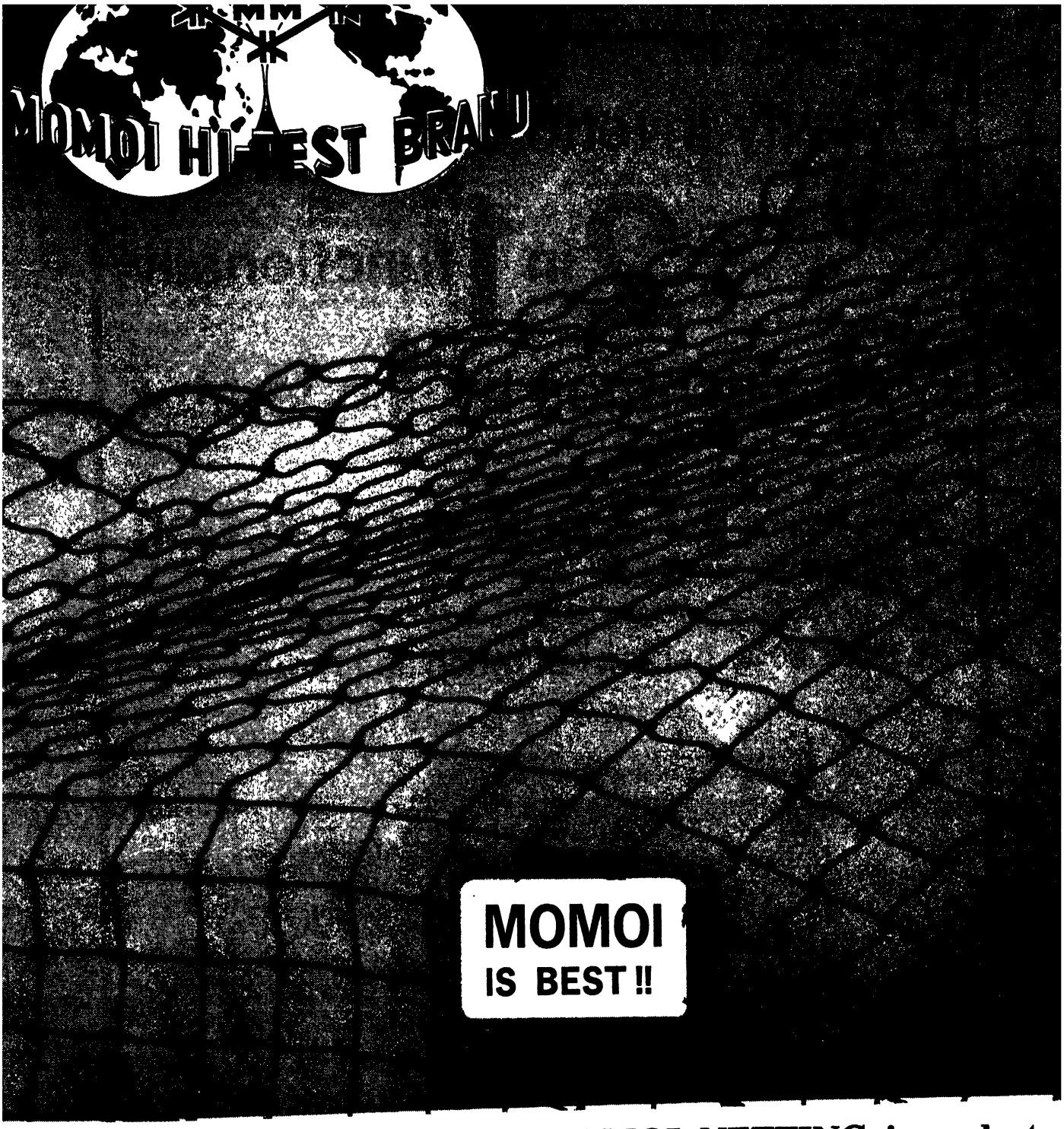

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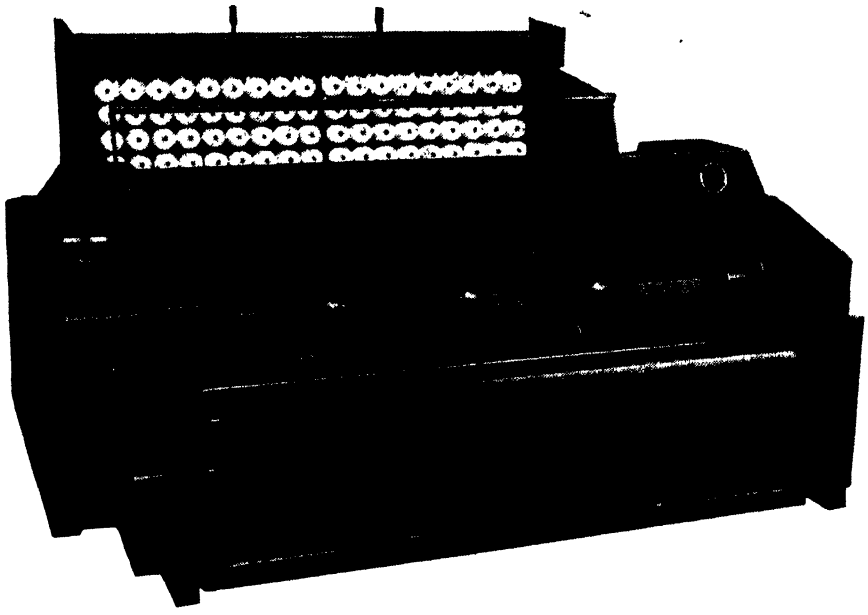

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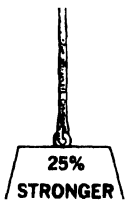

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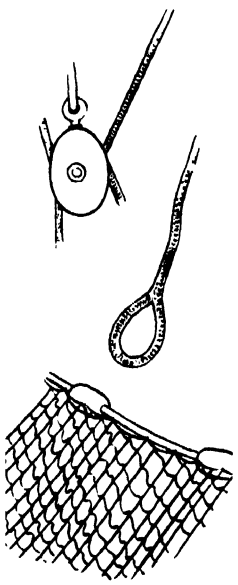

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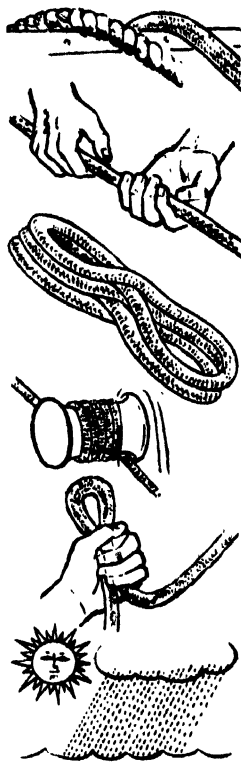

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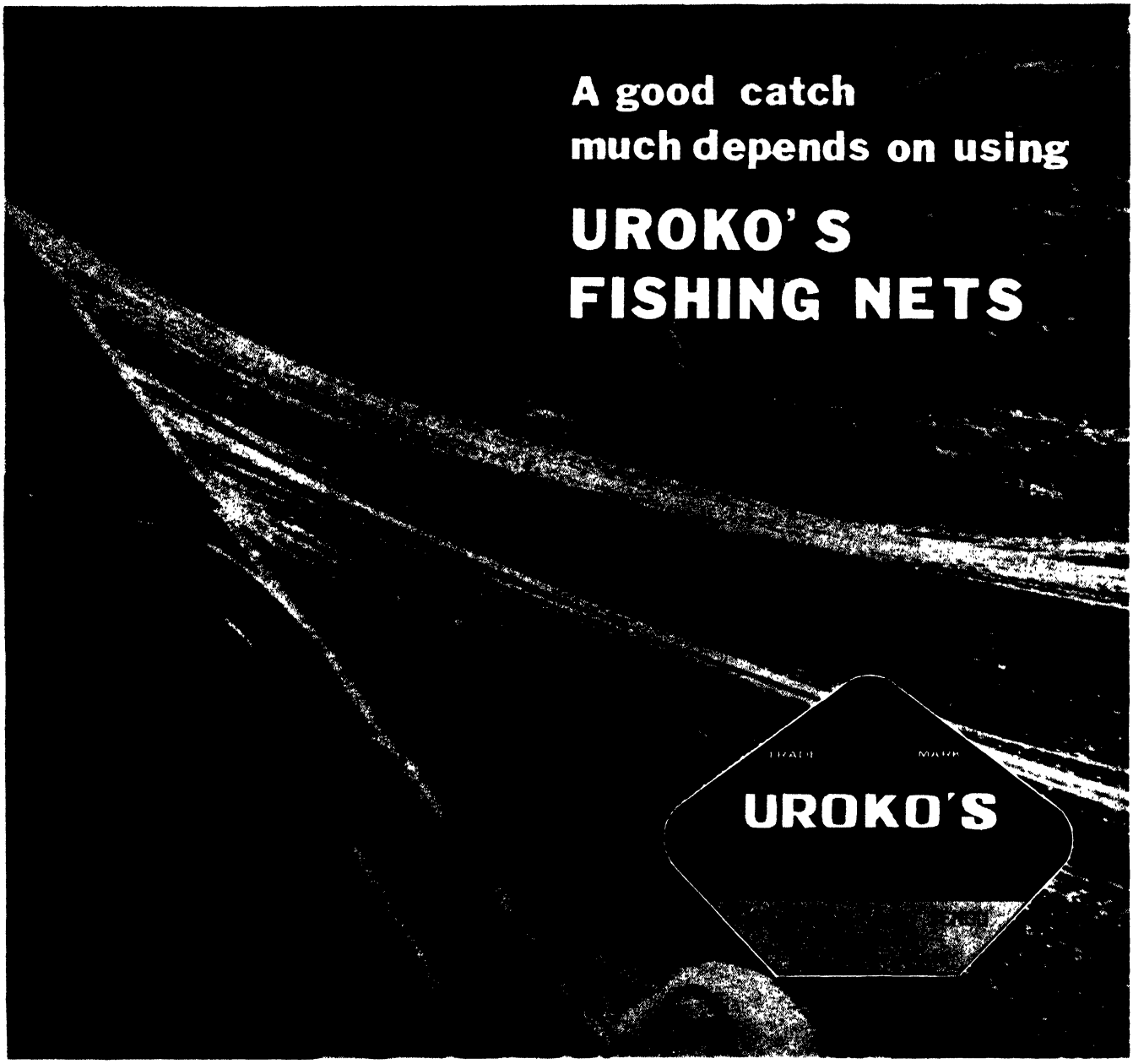

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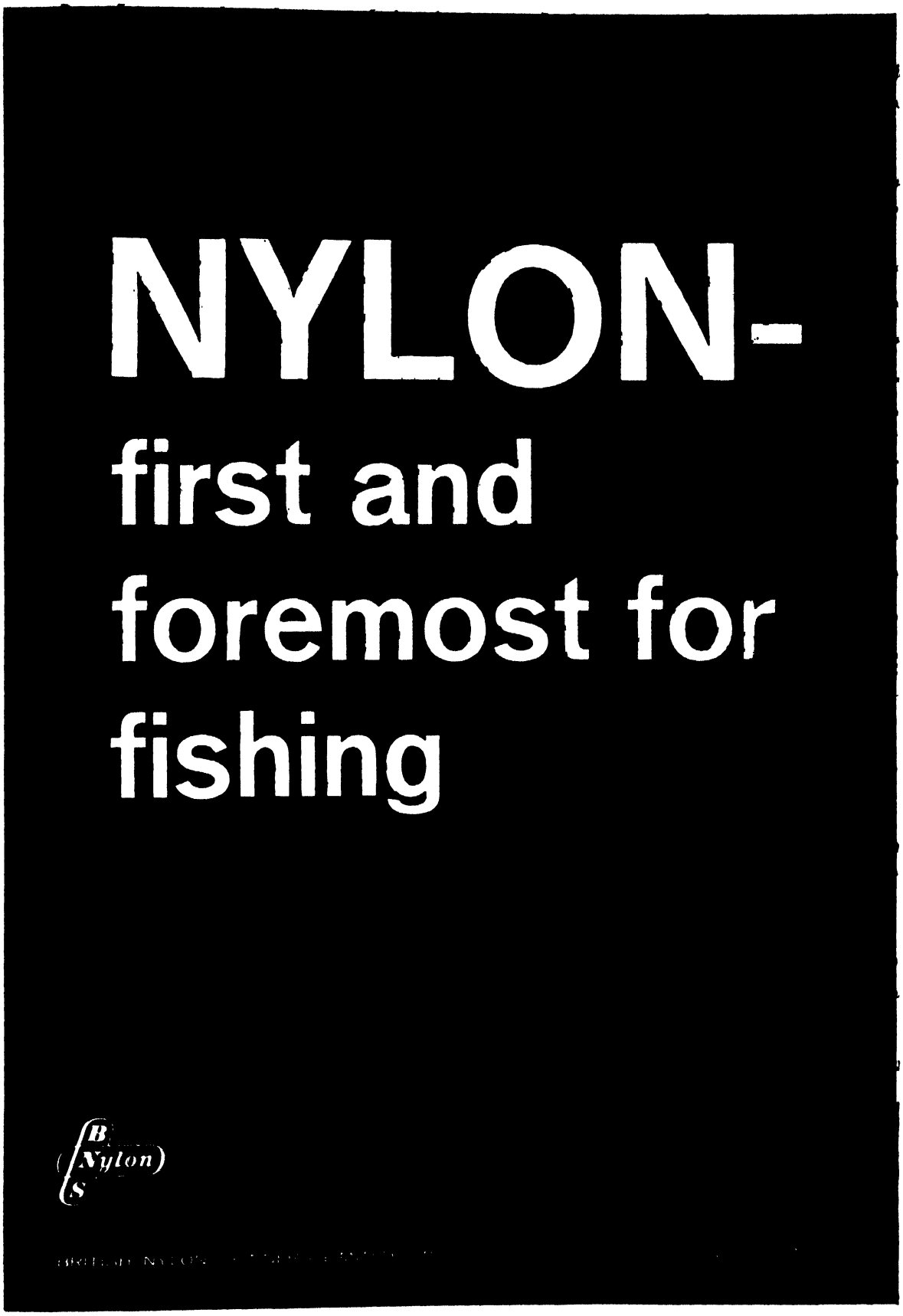
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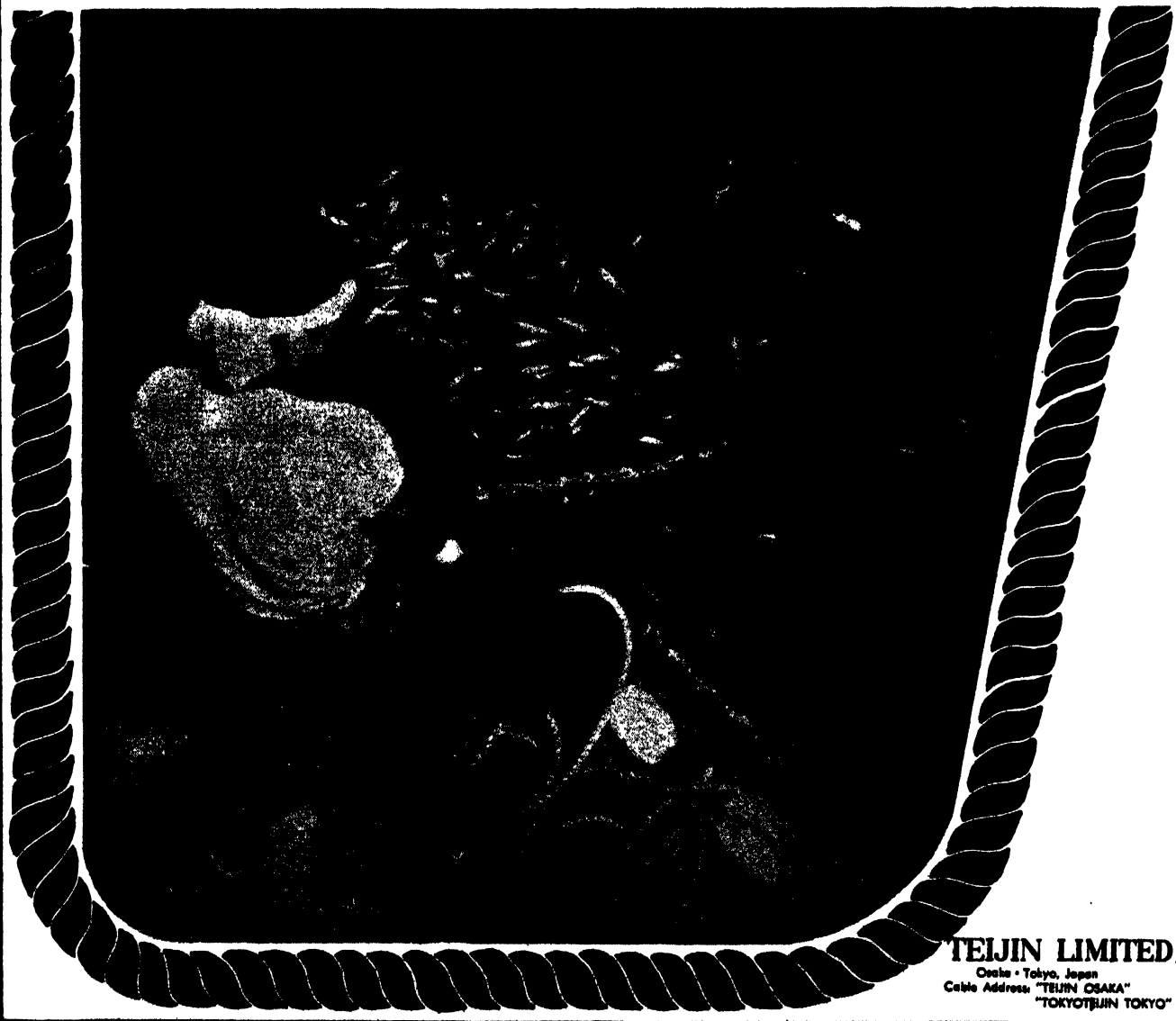

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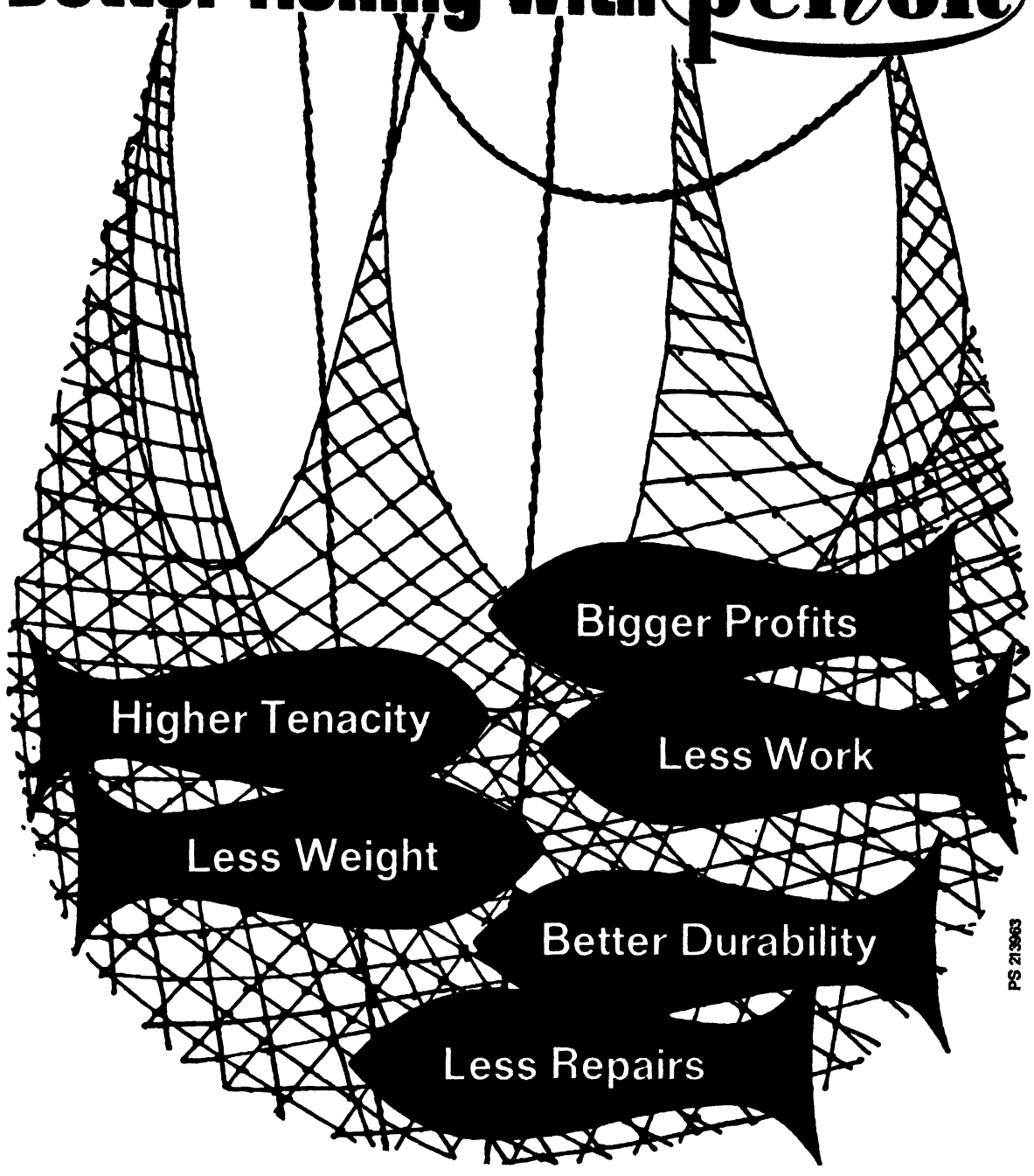

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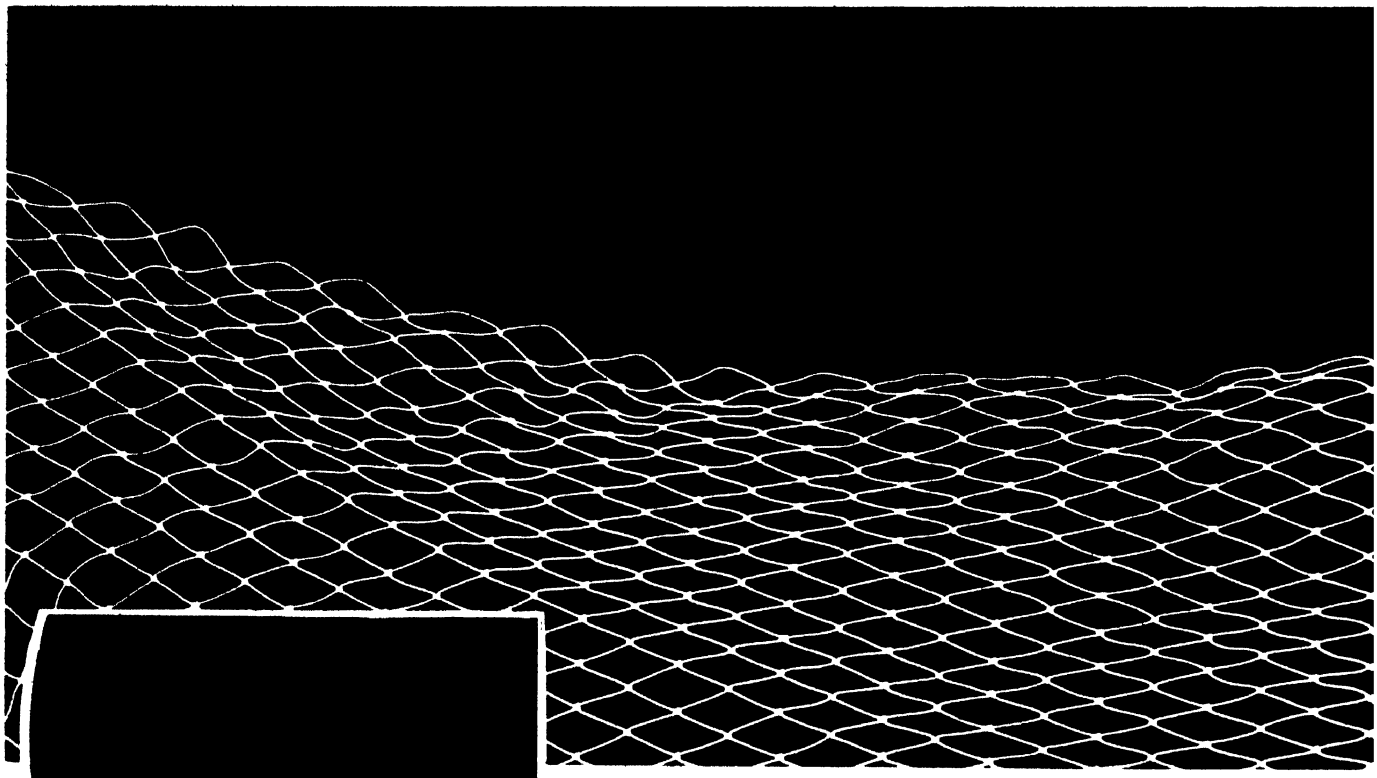

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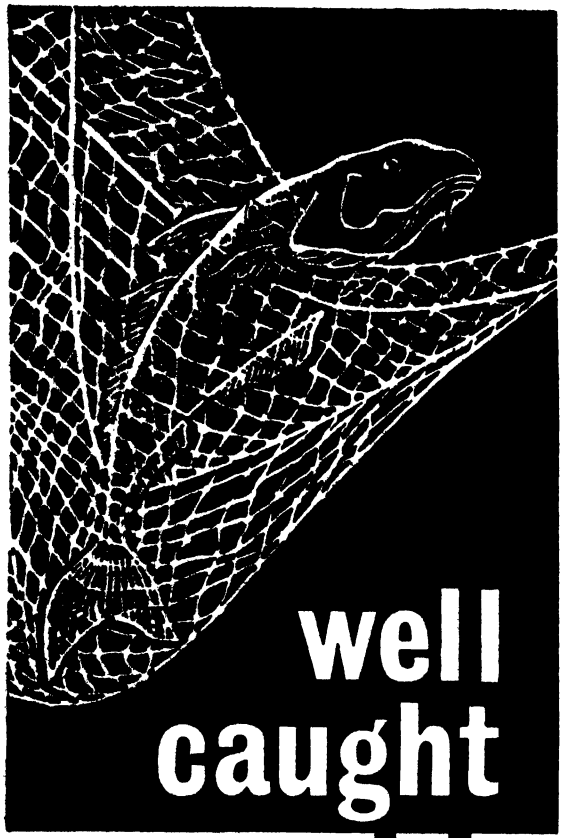

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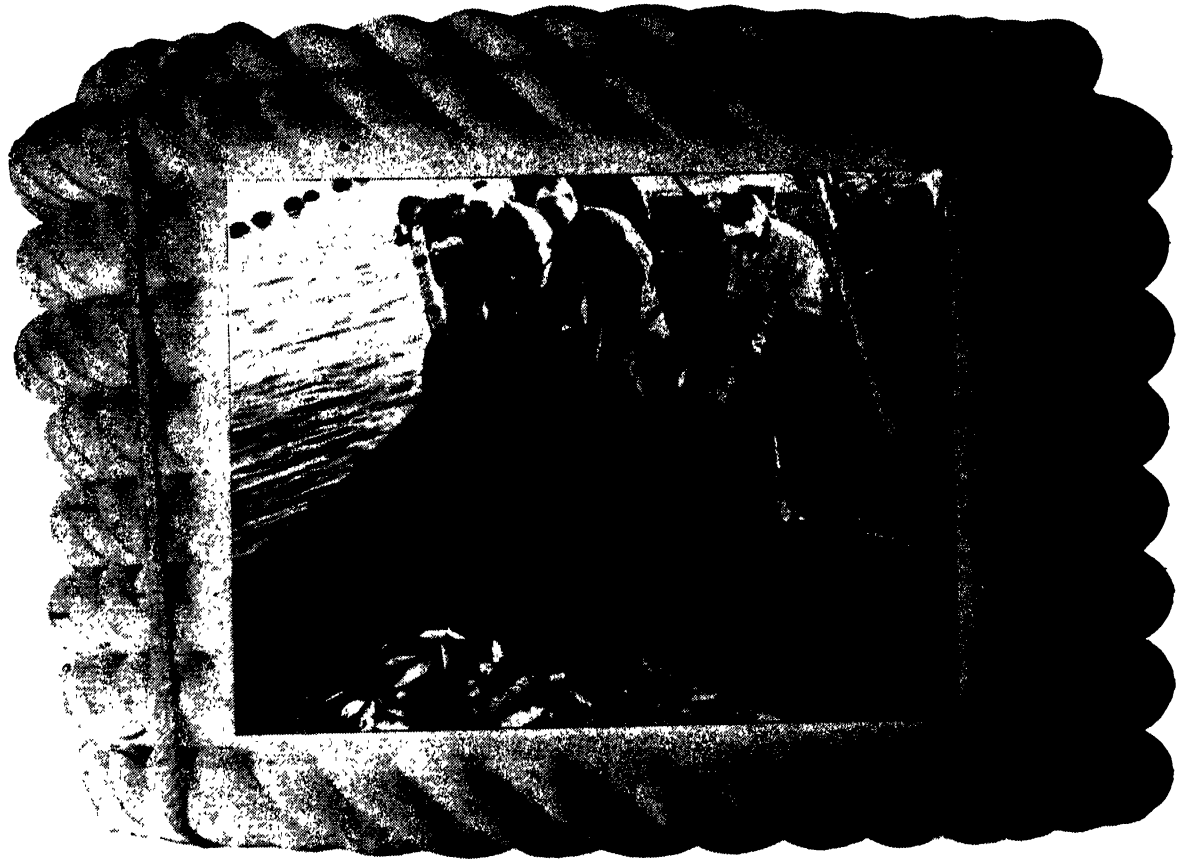

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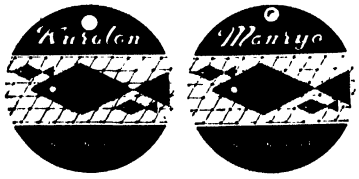

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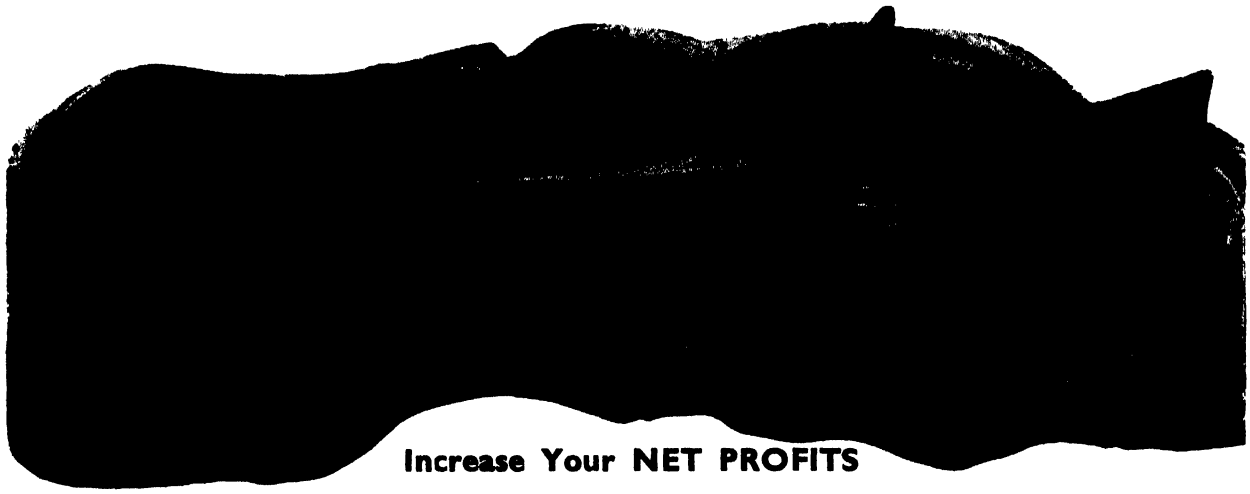

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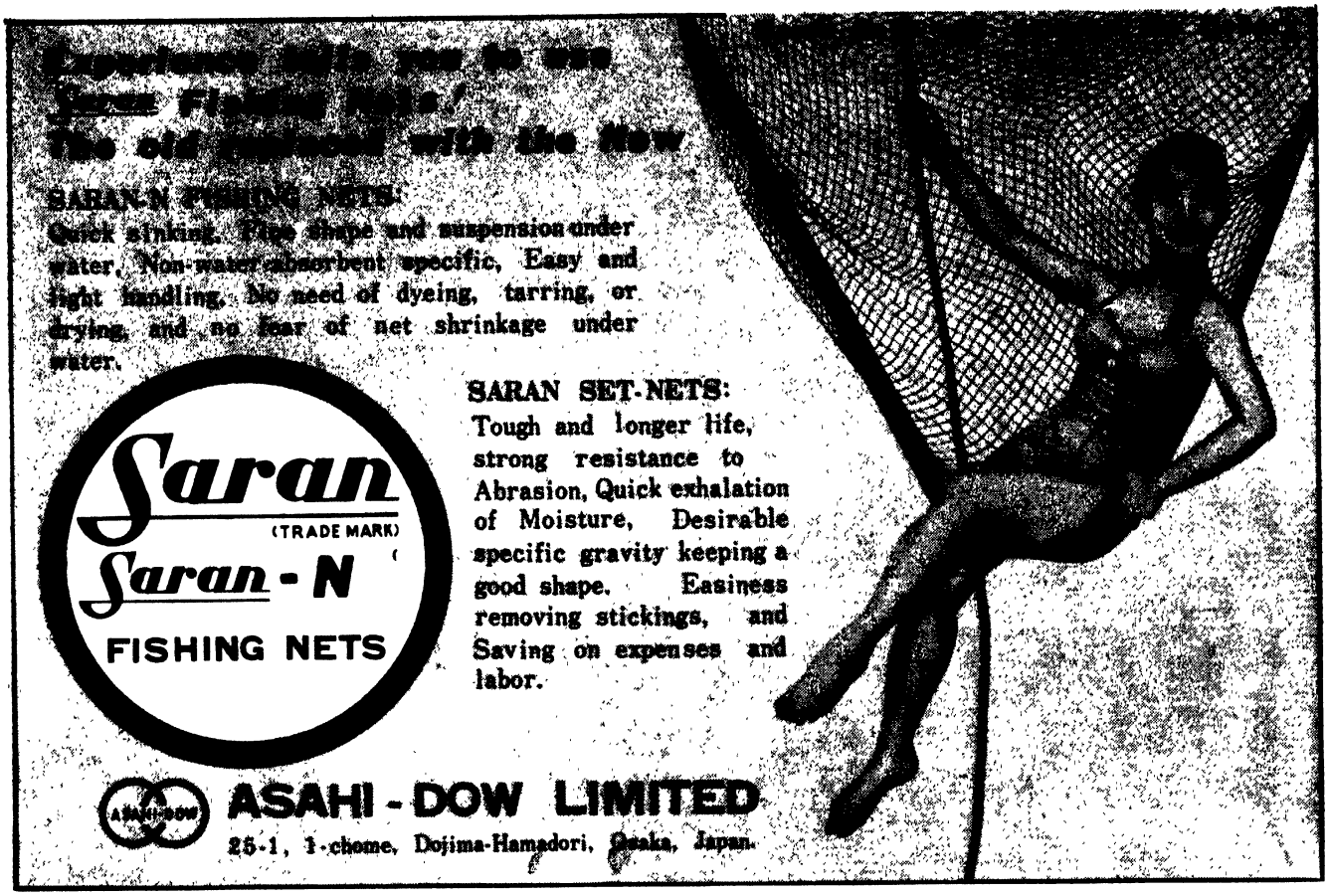

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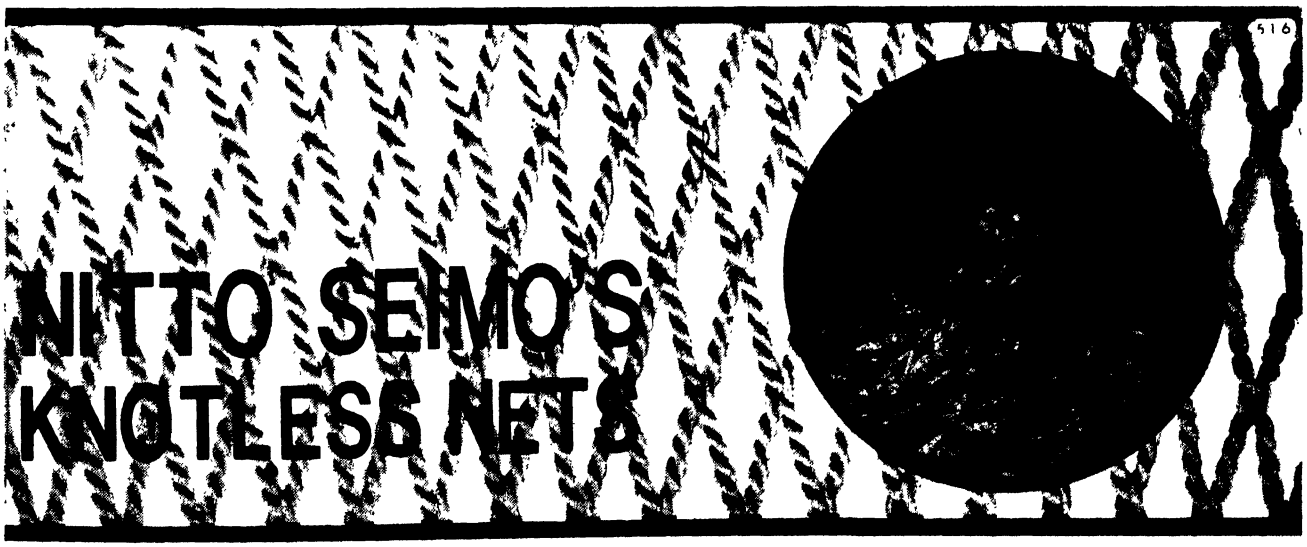

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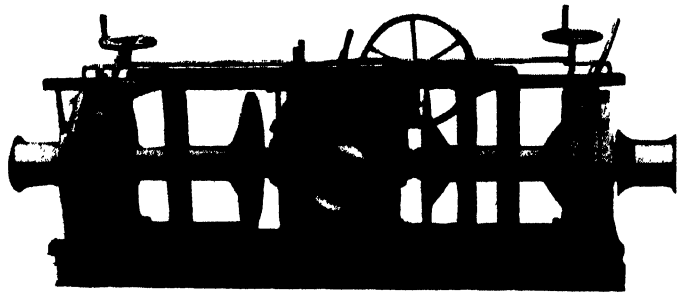

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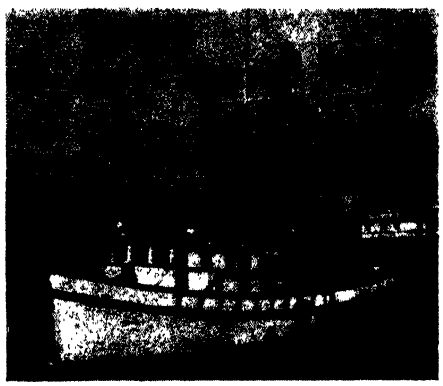

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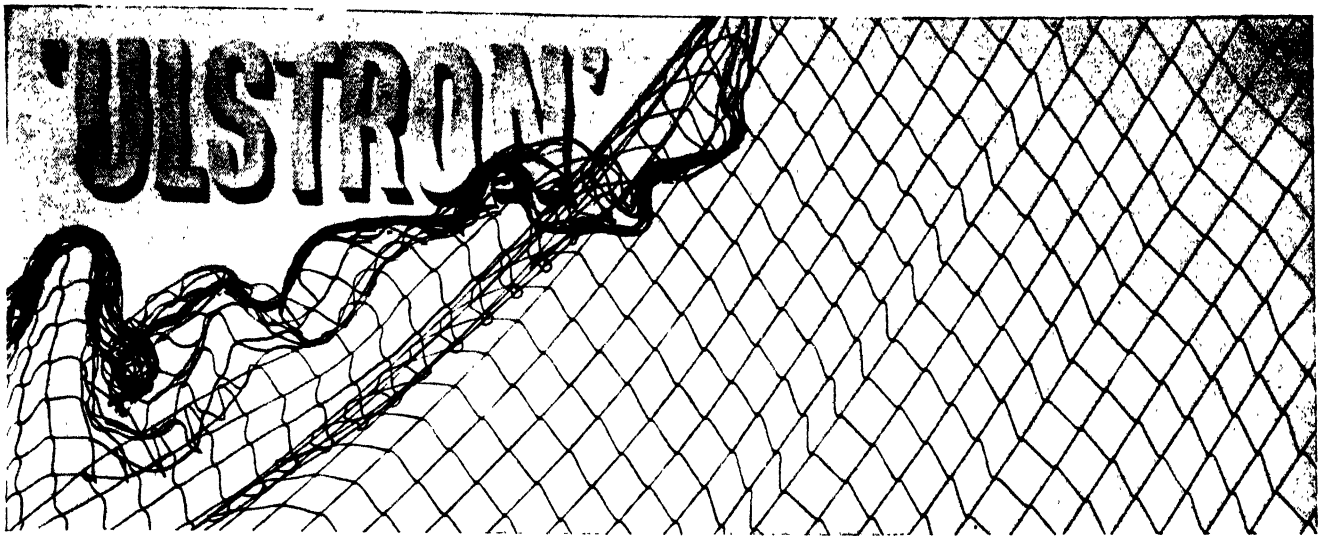

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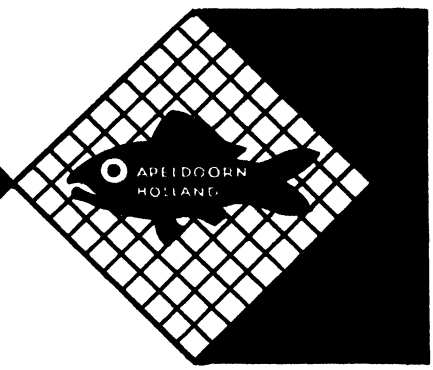

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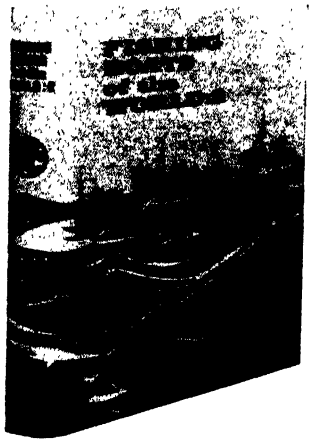

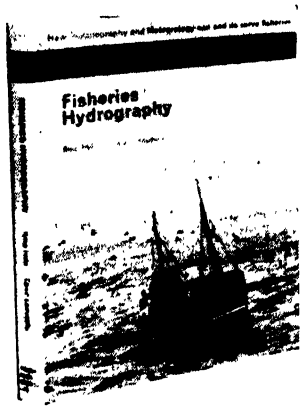

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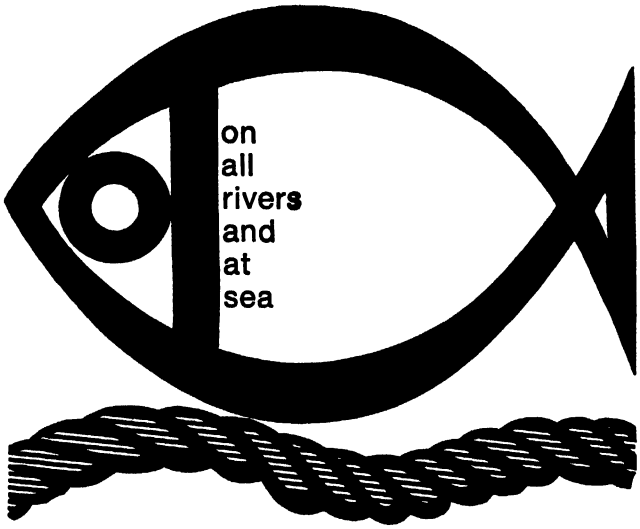

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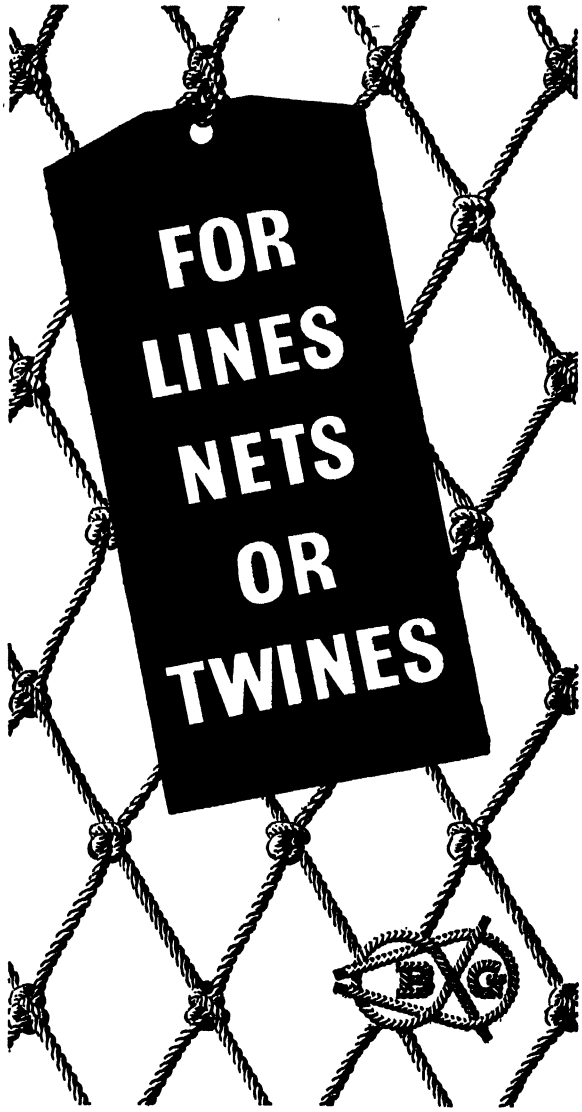

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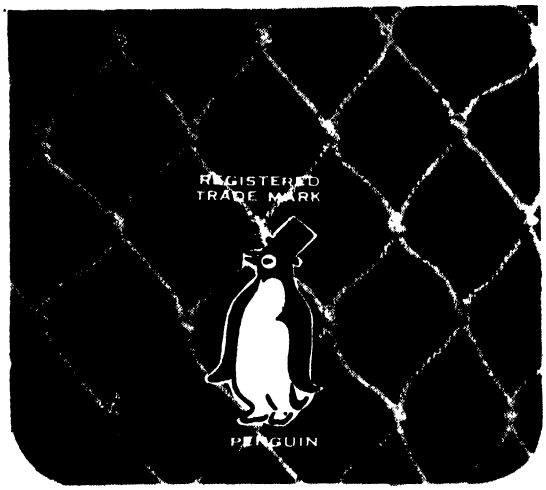

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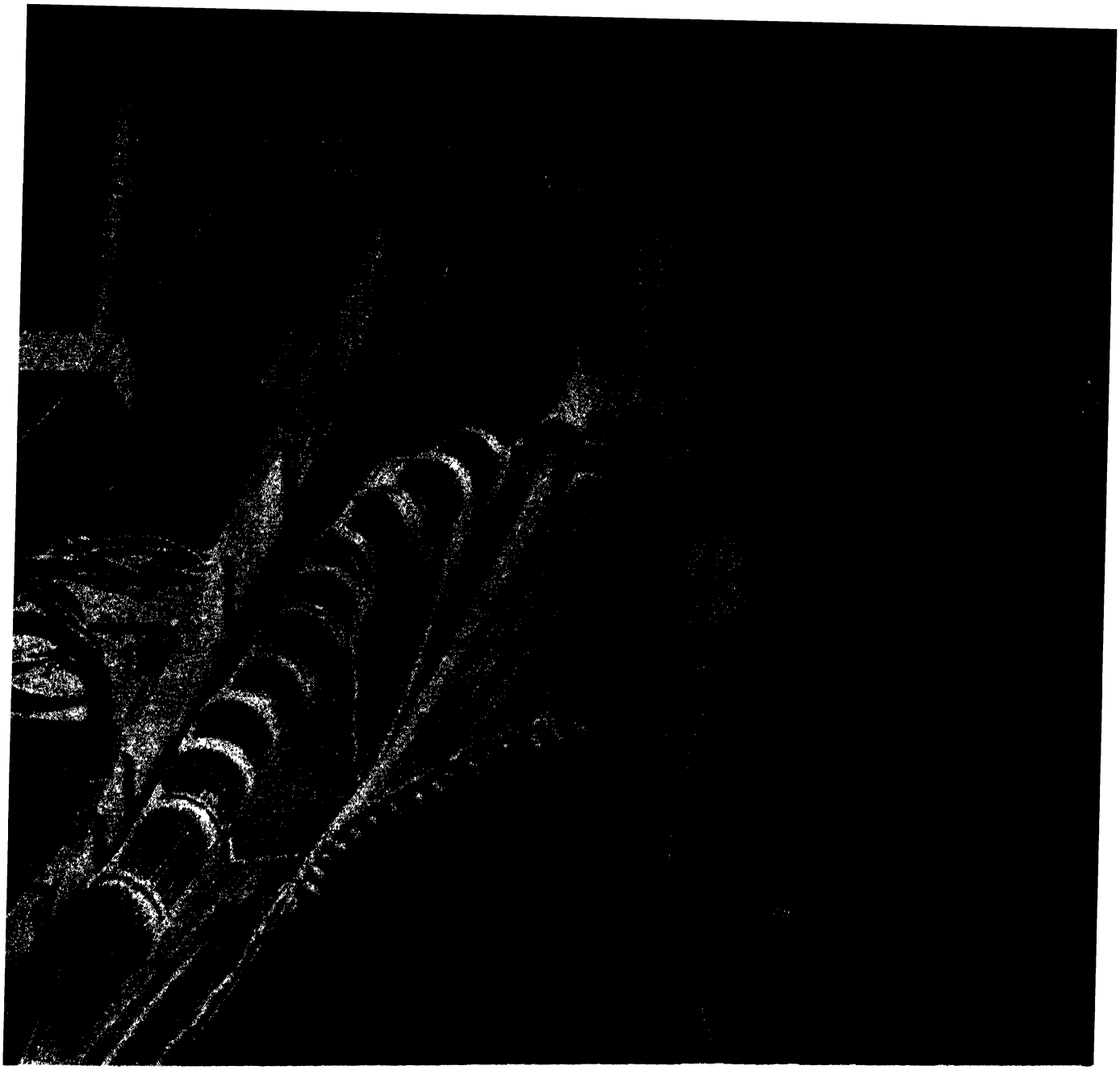

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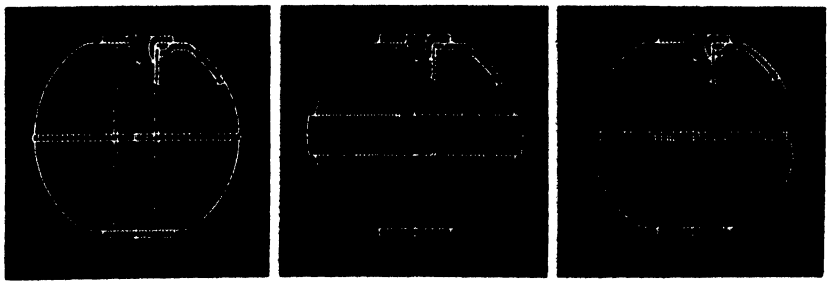

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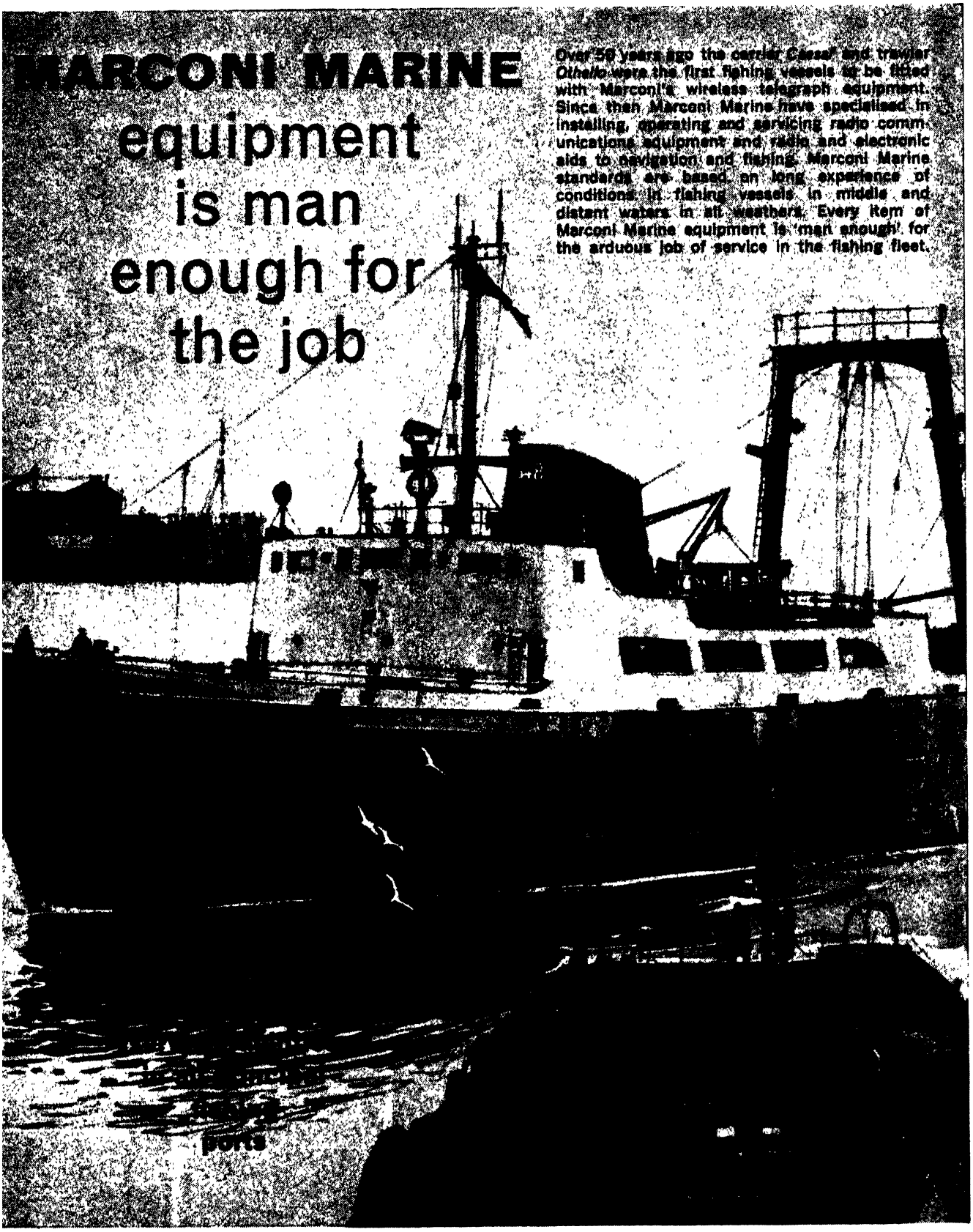

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The Sterntrawler—A Decade's Development in Trawl Handling

Abstract
The development of big sterntrawlers started by investigating the possibilities of processing the catch at sea. It was found that production lines inevitably crossed on a large sidetrawler and that the freeboard with shelter decks became too high for handling fishing gear. These difficulties disappeared when operating the gear from the stern. The problem of lifting the heavy gear on board at the stern was overcome by building a ramp over which the gear could be hauled without the time-consuming splitting of the codend to bring the catch on board. The first big sterntrawlers were factory-ships, such as the converted *Fairfree*, which led to improved types such as the *Fairtry*, *Puschkin* and *Majakowsky* class. Fishing conditions and the size of the vessel must be given due consideration in the design and construction of sterntrawlers. Matters which are of minor importance on large vessels may be of critical importance on smaller vessels. On the other hand, as smaller vessels normally work under better sea conditions, some problems can be dispensed with. Apart from more space for fish processing, sterntrawlers now have advantages over the sidetrawler in faster and almost fully mechanised handling of the trawl. The paper then describes the various types which have been realised to date and discusses ways and means for arranging the deck and winches for operation of the trawls over the stern. The future of fully mechanised sterntrawling is brought forward and the author points to the possibility of providing vessels, even as small as 26 m in length, with a stern ramp and tilting or fixed bipod posts to haul the gear. Summing up, the importance of close co-operation between the shipbuilder and gear technologist towards further development of sterntrawling is emphasised.

Le chalutier à pêche arrière—Comment il a revolutionne la manipulation de chalut au cours de ces dix dernieres annees

Résumé
La construction des grands chalutiers à pêche arrière résulte des recherches sur la possibilité de traiter les prises en pleine mer, à bord du bateau. Sur les grands chalutiers pêchant par le côté les opérations de traitement amènent inévitablement un croisement des chaînes de production et la hauteur de franc-bord de ces bateaux devient excessive et rend difficile la manipulation de l'engin de pêche. Cette difficulté disparaît lorsque l'engin est manipulé par l'arrière. Le problème que posait le relevage par l'arrière d'un lourd engin de pêche a été résolu par la construction d'une rampe sur laquelle l'engin peut être relevé, évitant ainsi la perte de temps provoquée par les remplissages et vidages successifs du cul de chalut. Les premiers chalutiers à pêche arrière furent des navires-usines tels que le navire transformé *Fairfree* sur lequel furent basés les projets relatifs à des types perfectionnés tels que les bateaux de la classe de *Fairtry*, *Puschkin*, *Majakowsky*. Les conditions de pêche, les dimensions du bateau ainsi que sa distribution interieure doivent faire l'objet d'études attentives avant d'établir les plans du bateau et de procéder à sa construction car des détails d'une importance relative dans un grand bateau peuvent avoir une importance capitale dans d'autres bateaux de dimensions plus réduites; de plus, ces derniers travaillant normalement dans des conditions de mer plus favorables, certains problèmes ne se posent pas. L'installation de la rampe à l'arrière offre non seulement plus d'espace pour le traitement de la prise, mais a également l'avantage, par rapport aux bateaux pêchant par le côté, de permettre une mécanisation presque complète de la manipulation de l'engin. L'auteur décrit plusieurs modèles construits jusqu'à présent et traite des critères et des systèmes d'aménagement du pont etd 'installation des treuils qui manipulent les chaluts par l'arrière. Il examine les perspectives futures et décrit également un chalutier à rampe arrière complètement mécanisé, avec une rampe arrière et un mât bipode basculant ou fixe pour hisser le filet (cette mécanisation pouvant équiper également des bateaux n'ayant que 26 m de long) L'auteur termine en mettant en relief l'importance de la collaboration entre le constructeur de bateaux et le spécialiste d'engins de pêche en vue du perfectionnement ultérieur du chalutage par l'arrière.

by
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El arrastrero con rampa a popa—como ha evolucionado la manipulacion del arte en una decada

Extracto
La construcción de grandes arrastreros con rampa a popa se debe a la investigación de las posibilidades de elaborar la captura a bordo. Se observó que al instalar maquinaria elaboradora en un gran arrastrero que pesca por el costado era inevitable que las cadenas de producción se cruzasen y que el francobordo adquiriese demasiada altura para manipular el arte con facilidad. Esta última dificultad desaparecía cuando el arte se manipulaba por la popa. El problema de meter a bordo por la popa el pesado arte se solucionó construyendo una rampa por la que la captura se podía izar de una vez a cubierta, evitando así la lenta tarea de llenar y vaciar el saco repetidas veces. Los primeros arrastreros grandes con rampa a popa fueron buques fábrica como el transformado *Fairfree*, en el que se basaron modelos mejorados como los de la clase *Fairtry*, *Puschkin*, y *Majakowsky*.

Las condiciones de pesca, las dimensiones del barco y su distribución interna tienen que ser objeto de cuidadoso estudio antes de preparar los planos de formas y proceder a la construcción, ya que detalles de poca importancia en un barco grande pueden ser vitales en otro pequeño; además, los barcos pequeños, por trabajar en condiciones de mar más benignas, no plantean ciertos problemas.

El arrastre por la popa no sólo deja más espacio para la elaboración de la captura, sino que tiene la gran ventaja con respecto al arrastre por el costado de que permite mecanizar casi por completo la manipulación del arte. El autor describe varios modelos construídos hasta la fecha y examina los modos y recursos para la distribución de la cubierta y de las maquinillas que manipulan las redes por la popa.

Al examinar las posibilidades futuras el autor describía un arrastrero con rampa a popa totalmente mecanizado y un barco de solamente 26 metros de eslora con rampa a popa y pórtico basculante a fijo para izar el arte. Termina poniendo de relieve la importancia que tiene que el constructor de barcos y el especialista en materiales de pesca cooperen en el perfeccionamiento ulterior de la pesca al arrastre por la popa.

THE original ideas which led to the development of stern trawling were combined with the need for a trawler with a large processing deck. A conveyor belt system could not very satisfactorily be installed on a sidetrawler: production lines inevitably crossed. Furthermore, the high deck of a sidetrawler with an additional processing deck rendered the handling of gear more difficult.

Even such alternatives as the semi-shelter or trunkdeck ship could not fully solve the problem.

All these disadvantages are avoided if the catch is hauled in at the stern. Moreover, by this method various simplifications in trawling can be achieved by mechanisation. So the hauling-up ramp was thought of; as used on whalers. Such a ramp also offered the possibility of pulling in the entire codend in one operation. The laborious splitting of bags with larger catches could therefore be avoided and much valuable time saved.

There were, however, numerous sceptics who at once saw a danger of damaging the fish. Furthermore, it was also feared that difficulties could arise in hauling up large catches, as in fact was at first the case.

Now, after 10 years of progress, the actual possibilities can be considered in a clearer light. At the same time we realise a certain change in the problems. It is therefore interesting to recall some of the stages in this development.

The big factorytrawler

As early as 1945 a patent was applied for on the German side for a trawler with a stern-ramp. Similar efforts were subsequently evident in Great Britain and it was Chr. Salvesen & Coy., Ltd., there, which mostly specialised in whaling that had the courage to build the first experimental vessel in this line. The experiments with the converted vessels, *Oriana* and *Fairfree*, led to the construction of the new factorytrawler, *Fairtry I*, and later on to *Fairtry II* and *III*. Alongside this, in Germany, a fleet of 20 ships of the Puschkin-type factorytrawler were developed for the U.S.S.R. The experience gained with these vessels led to various new series being constructed in the U.S.S.R., Poland and in Eastern Germany —among others, the well-known Majakowsky Class and, on account of the special conditions prevailing in the tropics, the Tropic Type. The size of the vessel justified equipping the upper deck with a large number of technical aids for gear handling. Mobile warp trolley-rollers were, for example, developed on the Puschkin type to simplify handling the gear. The Majakowsky Class was fitted with swinging console gallows to meet requirements during trawling as well as hoisting the trawl doors.

The crew required for the complete processing of the

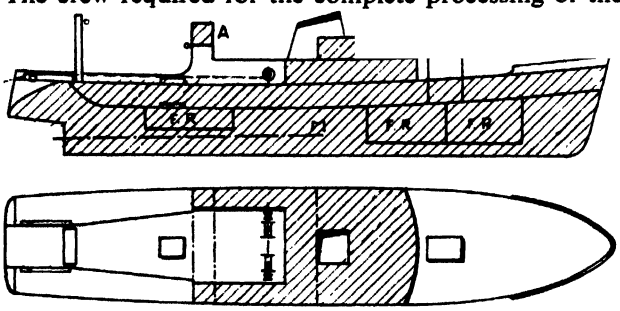

Fig. 1. Factorytrawler type (Fairtry, Puschkin, Majakowsky) *with normal diesel engine plant, voluminous superstructures, sufficient deck space for the trawl but separated navigation bridge B and trawl-bridge A.*

fish made large living quarters a necessity, which in turn required considerable superstructure. Consequently the navigation and the trawl bridge had to be separated so as to give an adequate view over the stern. In spite of the large superstructure, sufficient deck space could be kept free on this big vessel for unimpeded handling of nets (Fig. 1).

On newer German factorytrawlers, powered with diesel electric drive, the superstructure was eased forward on top of the forecastle so as to provide the argest possible trawldeck. If the normal diesel motor

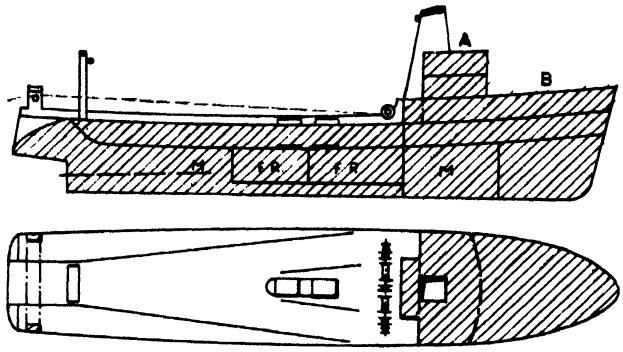

Fig. 2. Factorytrawler type (Heinrich, Meins, Heinrich Kern, Hans Böckler) *with diesel electric plant. Superstructures at fore-ship, long deck space and combined bridge A and accommodation in forecastle B.*

unit required a division of the hold fore and aft of the engine-room, by diesel electric drive, the hold could then be installed in the most convenient place, as far as trim was concerned, at midships (Fig. 2). Disadvantages soon arose, however, because of the position of the bridge and trawl winch, which were too far forward, disadvan, tages which were apparent from the high acceleration when pitching and from the poorer view to aft, to the ramp and gallows. Moreover, the living quarters of the crew were pushed still further forward, further in fact than a sterntrawler, according to its very structure-requires.

With a normal engine plant, the optimum design of the vessel made it advisable for the engineroom to be sited aft and the bridge at midships with an aft connected enginecasing. Consequently, a trawler with superstructure on one side was proposed, following the model of

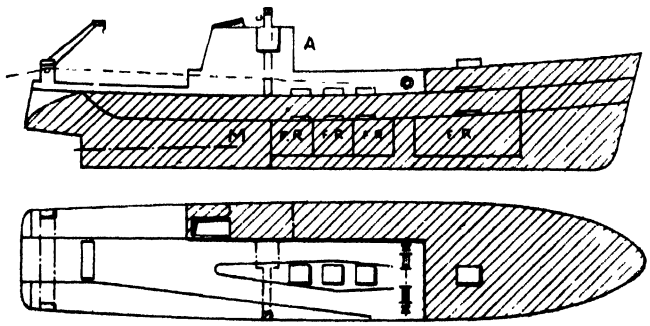

Fig. 3. Factorytrawler type (Colonel Pleven II) *with semi-side superstructure amidships and combined console bridge A.*

an aircraft carrier, with a combined bridge for navigation and trawling purposes hanging over the trawldeck (Fig. 3). Another solution with the same purpose in mind is the trawler with superstructure on both sides and a combined ferryboat type of bridge. This had already been suggested as a possible alternative several

years ago but had not been realised before 1962 (Fig. 4).

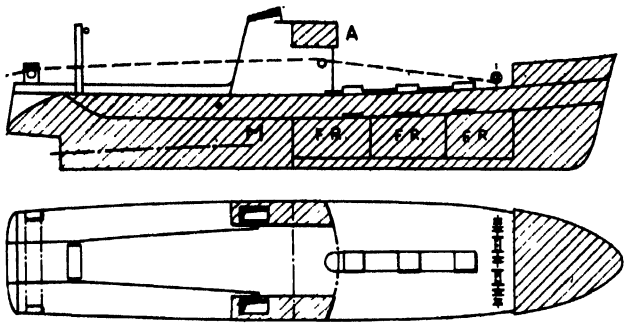

Fig. 4. Factorytrawler type (Tromsøy I, Lofottral I, II) *with two sideward superstructures and combined ferryboat-like bridge A.*

The partial lengthening of the actual trawldeck aft was meant to serve for laying on deck the long trawl wings but on a rolling ship the floats, shackles and winglegs became hooked up and entangled during the process of handling the gear if both wings were very close together. Since the trawl is V-shaped, the deck lent itself to a corresponding division. With side passages for operating the netwings and laying them out on the deck, the customary midship superstructure, desirable also from the point of view of the construction, was made possible. Behind this deckhouse the trawlwinch is installed, which now comes as near as possible to the gallows. In this way the trawling gear is "split" as early as possible during the hauling-up operation with the long wings on both sides (Fig. 5).

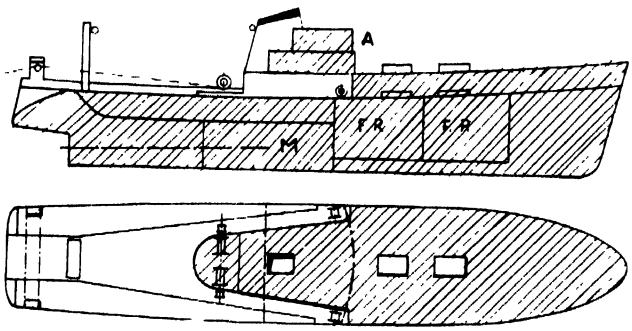

Fig. 5. Factorytrawler type (Narwal) *with diesel engine plant at aft-V-shaped trawldeck and combined bridge amidships A.*

In this case, with ships of over 40 m in length, it is possible to install the engineroom aft behind the fish hold which is preferable to all other possibilities. Due to that arrangement, even for the diesel electric trawler, a more practical distribution is achieved because cable lengths are shorter, control is better and one bulkhead is saved; more practical, that is, if on the other hand good trim conditions can be effected in the ship through skilful arrangement of the tanks.

The deep-sea trawler

Medium-sized sterntrawlers, i.e., midwater and deep-sea trawlers, require a relatively simple and particularly stout deck equipment to be able to compare the new system of handling the gear favourably with the previous type of sidetrawler. Since the deck area of these vessels is limited, an especially well thought-out balance between naval architects' interests and those concerning the pure fishing technicalities had to be struck.

The desired compromise solution provided a deck area aft for hauling up the cod-end and some fairly wide gangways leading forward to the foreship. At first the trawl winch was built round on three sides, set into the superstructure, and the bobbin groundrope was hauled over the trawl wings, which were dragged up behind the winch. Disadvantages due to the accumulation of the fishing gear, and particularly the trawl wings, behind the winch, could be avoided by extending the gangways at the side of the winch as far as possible towards the fore part of the ship.

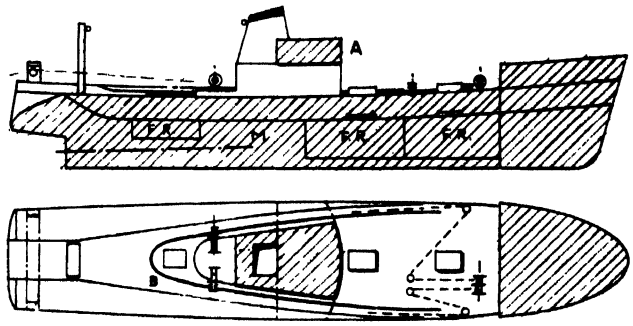

Fig. 6. Deep-sea trawler (Stanislava, Mare de Labrador, Juan de Urbieta) *engine at aft, combined bridge amidships A — and sideward tracks for the trawl wings B.*

Efforts to handle the Pareja gear, of about twice the bottom gear length in comparison, originally suggested this course (Fig. 6).

By using additional warping heads or similar drums on the trawl winch the job of releasing the warps from the trawlboards was saved, with a gain in time of about five minutes. At the time, the trawlboards were pressed flat against the gallows by this action so that work could be carried on without any danger.

Such warping heads or gilson drums offer the most varied combination of winch arrangement:

(a) On the same shaft.
(b) Gilson drums on the counter shaft.
(c) Gilson drums on a separate winch or winches, serving perhaps a dual purpose as ice or unloading winches.
(d) Combined trawl warp, gilson and hauling drums separated on each side of the ship.

Solution (b) is contemplated here especially for smaller vessels.

With medium-sized vessels good possibilities were presented for comparison with the previous type of ship, the sidetrawler. The sum total of all the direct and indirect advantages, which clearly outnumber the disadvantages (including, among other things, higher building costs), only now become fully obvious. The most vital advantage was the shorter time required for handling the nets; this lengthened the active fishing time, which in turn produced on an average a 20 per cent profit in terms of the valuable "trawl on the bottom" time and a correspondingly better result in the catch.

This revolution and change to the new type of vessel brought with it also a change of the crews from the old ships to the new ones, which enabled the shipowners of the latter to have a good selection for crewing the vessels, so the technical advantage was further strengthened by these personal influences. Crew problems on the older type of vessel compelled shipowners in several countries who were still holding back, to invest in this new solution.

Different basic conditions for near-water and coastal trawlers

All the disadvantages which are of little consequence with distant-water trawlers, for example factorytrawlers and deep-sea trawlers, are of greater significance with smaller vessels. For this near-water type of vessel the construction methods must be adapted to the general weather conditions prevailing on the particular fishing grounds. Often these small fishing boats work in relatively calm waters and this therefore permits solutions which would be impossible for rough seas.

In recent years two different ideas have been offered for this type of craft. One was the type without a ramp, built with a bipod post which in some cases was tiltable. The shipowner's fear of possible damage to the fish on the ramp gave place to the idea of splitting the bag on sterntrawlers too. Having relatively calm sea, only the wings, with groundrope and headline, are hoisted over the bulwark aft. Then the bipod post hoists the bag part of the codend up out of the water and swings it out over the deck-ponds. On the backward swing of a tiltable bipod post, or by means of an additional codend derrick, the codend is again shot into the water so that the fish

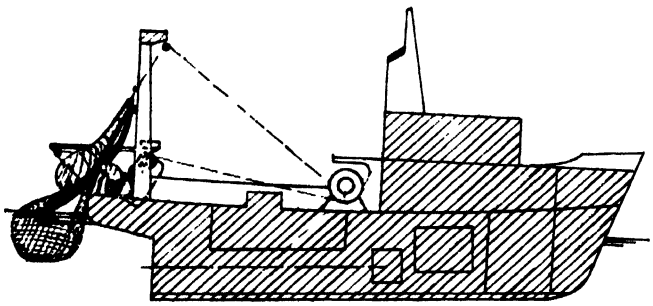

Fig. 7. Near-water sterntrawler without ramp but bipod post with gallow consoles and codend derrick.

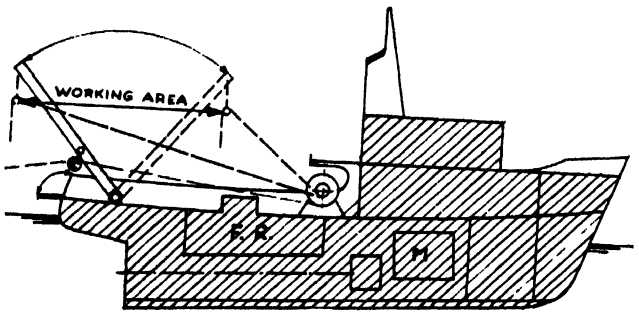

Fig. 8. Near-water sterntrawler with turnable gantry.

can be swilled quickly back again. This can be accomplished in rythmical succession in a really short time (Figs. 7 and 8). The larger the catch, however, the greater the time-saving, which the use of a ramp has over this method.

The sterntrawler with ramp, which is basically intended to save hauling time, goes a completely different way. Even if the average catch is relatively small, this vessel, without any further disadvantages, is better prepared to handle the larger catches in seasonal periods, too. The installation of a short ramp is possible even on ships of up to 28 to 30 m. The codend is guided by the gentle curving of the ramp in this case and is brought up without being bounced along against the stern. Damage to the fish by friction is impossible due to the special construction of the codend.

The codend is hauled up on deck in the main direction of the ramp by means of a hoisting block and emptied out by the tilting tackle on the fixed bipod post. A codend derrick, of some 4 m in length and pointing aft, takes care that the gear is lowered into the water behind the swirl of the ship's wake.

A ramp for hauling up the voluminous fore part of the gear and also occasionally used for hauling the whole codend, was considered as a very promising alternative solution. Indeed in this case, through the combined work of the tilting tackle on the bipod posts and the shooting tackle on the codend derrick, an operations area comparable with that employing the swinging posts, and possibly even more favourably sited, could be created; this would also permit a similar division of the contents of the codend (Fig. 9). The strong installation of the solidly built-in

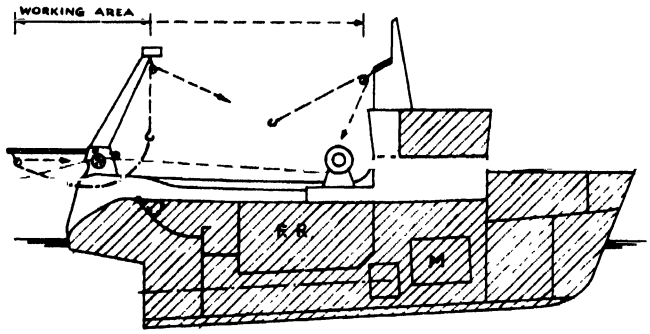

Fig. 9. Near-water sterntrawler with bipod gallow post, fixed codend derrick working with both blocks.

bipod posts and codend derrick guarantees safe working in all weather conditions. The longer trawl tunnel or lengthening piece, which might perhaps be necessary, could be compensated many times by the advantage of having a ramp available and consequently a better control of the gear. If, in addition, it is possible to tip the contents of the codend out under deck, the gear is again ready for shooting only a few seconds later, even in cases of very large catches. The significance of this in shoal fishing should be considered. The extra cost of protecting the working deck could, in the majority of cases, be more than compensated. This solution, after all, permits even the most sceptical shipowner to reconsider his prejudice without any disadvantage compared with his more progressive colleagues.

This system of tipping out the entire codend can finally be put into effect on ships of up to 26 m in length,

taking into account the length of the ramp as a usable extension to the deck. It is possible to combine the cover of the filling hatch with the ramp as a swinging-table type of ramp. To achieve the required security, this flap can even act as a bulwark when lifted up aft. The codend is hauled up only on this flat type of ramp and, after the codline is opened, is emptied out by the tilting of the flap. With a suitable device for opening the codend a little more forward and a holding device at the extremity, even the expensive bipod posts can be spared on such a type of craft (Fig. 10).

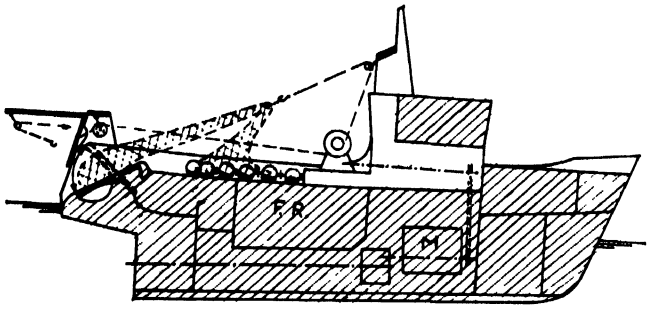

Fig. 10. Sterntrawler with turnable ramp without bipod post.

Where the side spaces are long enough this deck equipment, developed for the single towing trawler, offers the possibility also of handling a Pareja trawl, as already mentioned in connection with midwater trawlers. If one compares the usual practice in Pareja fishing as we know it at present with these new possibilities, there are even greater advantages than with the handling of one-boat trawls. The tremendous simplification of the manual work by extensive mechanisation produces a saving in time which is about 30 per cent higher than with hand-laboured vessels. Consequently, with this 30 per cent longer active fishing time, a corresponding increase in the results can be expected (Fig. 11).

Towards fully automatic trawling

Although school fishing is now an almost fully automated business, using light and electricity effects as well as pumps, is relatively complicated to introduce into net fishing methods. The purse seine can be handled automatically, particularly when one thinks of pumping out the purse in school fishing. These possibilities cannot be directly transferred to trawl fishing.

The trawlnet is always working in a water current, i.e., pulled in a constant direction. Also the instances are too few when one can really count on constant size of fish in the catch. Finally, any possible automation must also be capable of working in different weather conditions. With these basic conditions and requirements in mind one can develop a similar thought in terms of trawling.

A development such as this goes forward step by step. When the movement of the trawlboards at the stern were found to be too violent when the ship was pitching, guideways and fixed attachments were designed. When the handling of the wings on the aft deck was found to be too awkward on a heavily rolling ship, long side alleys for splitting and laying the wings on deck in one pull were devised. (Fig. 12a). If the de-shackling of the trawlboards and going round them with pennants proves too troublesome and awkward, we can install a pair of swinging arms, perhaps in the form of guide-rails, to allow pulling the sweeplines or legs up to the foreship by using trolley rollers. In this way, the laying of the trawl gear on deck is fully automatic (Fig. 12b). The last bit of hard work in handling the nets, which requires six men on board, will then be spared. With a saving in manpower there is likewise a saving in accommodation on board and the extra cost of installing the swinging arms and guide-rails on deck will be more than offset by this advantage.

The flap-type ramp makes it possible to empty the codend with the tilting tackle and this leads to the final problem, which is the connection between the hoisting tackle and the splitting strop on the codend. The length of this line has to be adjusted according to the length of the available gear deck. If this last piece of manual work were not so simple, some automatic facility would have to be found here too.

These suggestions are not final solutions but examples which will surely, in the future, lead to still other related ideas.

Trawl gear and fishery ships

Net and gear constructors will no doubt agree that the sterntrawler is a new development in naval architects' construction in which the shipbuilder has taken a lot of trouble to adapt his product to suit the gear constructors' work. What could and can now be done by the netmakers to meet the efforts of the naval architect?

Ten years' practical experience with the new type of vessel has brought with it some alterations in the trawl gear for sterntrawlers, which should not be forgotten. First of all, the codend was adapted to the requirements

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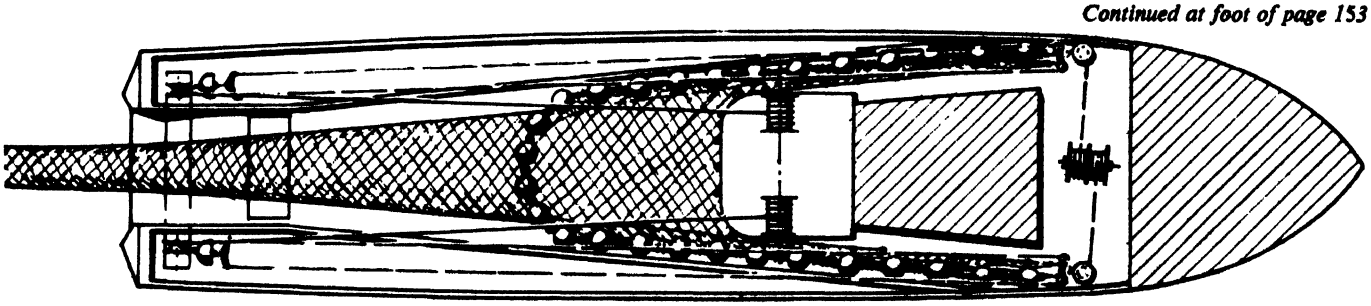
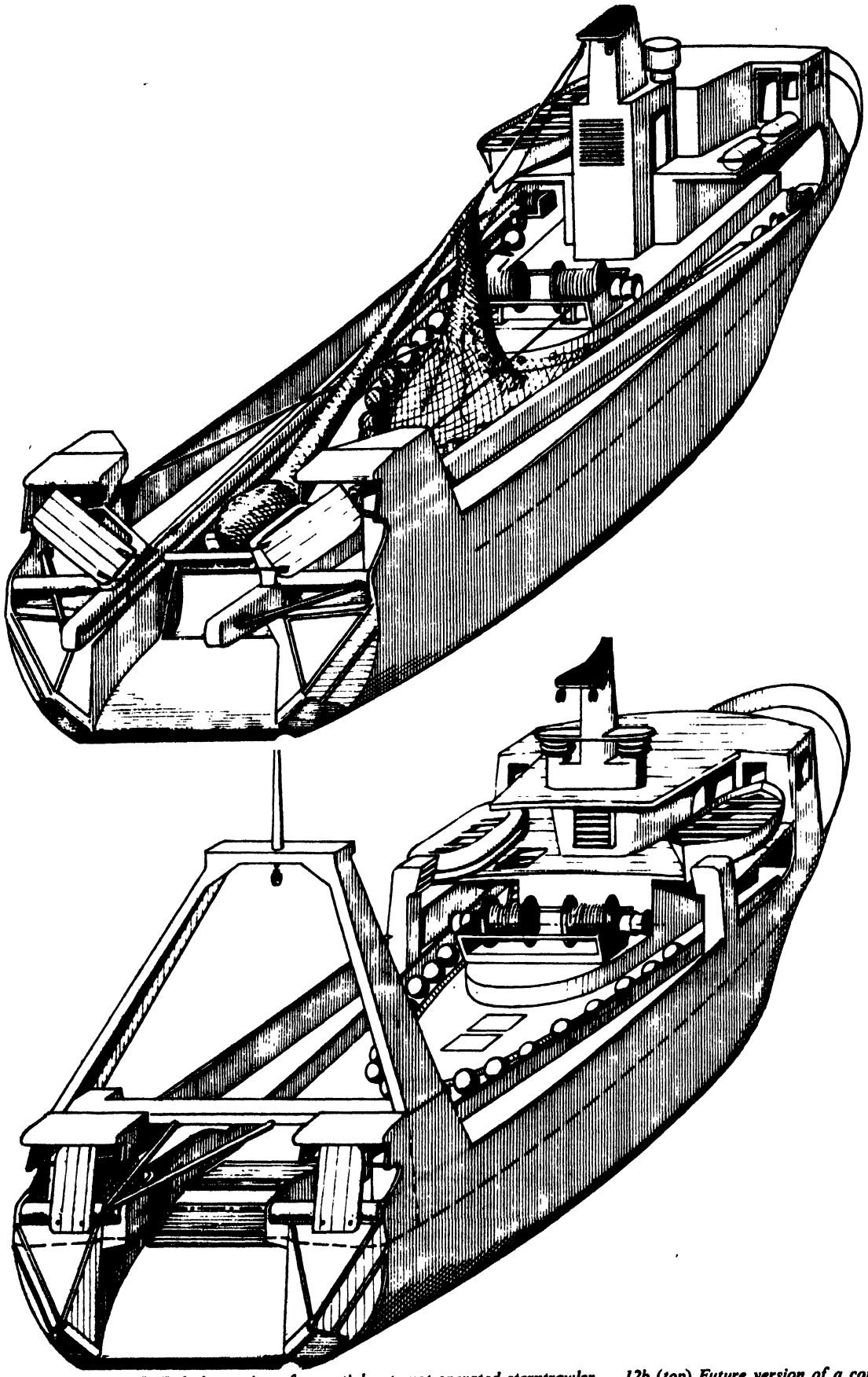


Fig. 11. Pareja sterntrawler with sidewards tracks for the trawl wings.



Figs. 12a and b. 12a (bottom) Today's version of a partial automat-operated sterntrawler. 12b (top) Future version of a complete automat-operated sterntrawler.

Some Small Stern Trawlers

Abstract

The paper describes some problems arising from stern trawling operations with small vessels. Bringing the gear on board requires a long deck space so that the smaller the vessel is, the more difficult the problem. A number of solutions have been proposed, such as cantilever deck houses with a winch installed far forward, or a deck arrangement as on an aircraft carrier with casings all on one side. On small ships of, say, less than 100 ft, such constructional changes cannot help as the available areas on deck are too small at the outset. The mouth of the net must then be brought to the stern and held there while the codend is lifted over. The use of a tiltable gantry is only one of several ways of doing this, but has proved to be very effective in use. The Unigan arrangement, as used on the *Universal Star*, has incorporated this method. Such gantries have been fitted in vessels up to 210 ft in length and have been developed for vessels as small as 50 ft. The functions of the tiltable gantry during shooting and hauling operations are described in this paper, and some of the fundamental construction problems concerning stern trawler construction are discussed and suggestions given towards their solution.

Quelques petits chalutiers a pêche arriere

Résumé

La communication décrit quelques problèmes découlant du chalutage par l'arrière avec les petits bateaux. Pour remonter le chalut à bord, le pont doit avoir un espace assez long, c'est pourquoi plus le bateau sera petit, plus le problème sera difficile à résoudre. De nombreuses solutions ont été proposées telles que: superstructures en cantilever de chaque côté du bateau avec treuil installé tout à fait à l'avant, ou bien arrangement de pont comme sur les porte-avions avec des revêtements d'un côté seulement. Sur de petits bateaux (jusqu'à 32 m) des constructions de ce type ne sont pas très efficaces car l'aire du pont est trop petite. L'ouverture du filet doit être halée justqu'à l'arrière du bateau et maintenue là pendant que le sac est monté sur le pont. L'utilisation d'un portique basculant n'est qu'une des nombreuses mainères de lever le sac et a prouvé son efficacité dans la pratique. Le système Unigan utilisé

by

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of a ramp. It was fitted with longitudinal or diagonal ropes as reinforcement and these absorb the whole pull, and it was divided into two or three longitudinal combs by vertical walls or seams. The latter improvement made the codend flat and more flexible for the curve in the ramp. The flat-lying position was often further improved by floats fastened at the seams, which made rolling impossible. The underside was fitted with hides and chafing ropes running lengthwise and close together. For emptying a heavily filled codend, a second opening was made at an appropriate distance from the original codline; for instance, by a ring-splitting connection. Indeed, this latter idea was subsequently used for separating and exchanging complete codends as necessary for transferring the catch or replacing damaged codends, etc.

Besides the alterations to the codend, the saving of one "false headline" together with one kite on the herring gears should be especially mentioned as this easily becomes entangled in the wake behind the ship when shooting. In order to maintain the same uplift a special float (an otter with wing-planes) was used, which is mounted just before the remaining kite.

On rocky bottoms the advantage of shorter lower wings had already become evident due to the fact that fewer stones are collected and so it turned out to be practical, when hoisting the trawl wings along the deck, to shorten the upper wings slightly too. The scaring effect of the longer legs compensated for the loss in wing length. Depending upon the conditions of the deck, a slight shortening of the legs is possible without catch reduction if, in this way, a more practical and satisfactory constructional distribution can be achieved.

If occasionally, in spite of the ramp which is there, one wants to bring the contents of the codend on deck by splitting bags, a longer tunnel or lengthener is required in order to have sufficient room in the net for swilling the fish back.

With still further mechanisation or full automation in the handling of the trawl, a certain adaption of the sweeplines and trawlboards may become necessary. In the case quoted, the length of the sweeplines would have to be restricted to the length that could be pulled in on board: some 80 per cent of the ship's length.

The laying out on deck of the entire trawl gear may render it advisable to divide the net with ringstrop connections to allow for replacing individual sections of netting in the event of damage.

These requirements and possibilities are mentioned only as examples of how the netmaker can adapt his work to the arrangement of the new vessel types. The more the shipbuilder is prepared to mechanise or automate the handling of the trawl, the more the net-maker has a duty to develop a trawl gear suitable for such automation. The advantage in design which is then achieved may well compensate for certain losses in catch capacity. Nevertheless, it is the task of the gear constructor to find such an adaption without vital loss to the catch results.

The development of the simplest automation and the production of trawl gear which has the maximum effect will, in future, call for a closer co-ordination between the constructors of fishing gear and those of fishing vessels. On behalf of my colleagues in the shipbuilding industry, I believe I can especially stress that we are prepared to do our very best to achieve this end.

sur l'*Universal Star* est basé sur cette méthode. Ces portiques ont été montés sur des bateaux de 70 m de long et développés pour des petits bateaux de 16 m. Leurs fonctions pendant la pêche sont décrites dans la présente communication. Quelques uns des problèmes fondamentaux relatifs à la construction des chalutiers péchant par l'arrière sont posés et des solutions sont suggérées.

Arrastreros pequeños con rampa a popa

Extracto

Describe el autor los problemas que plantea la pesca al arrastre por la popa con barcos pequenos. Para meter el arte a bordo se necesita una cubierta larga, de manera que cuanto más pequeño es el barco más difícil es el problema. Se han propuesto varias soluciones entre ellas al puente de mando cantilever con la maquinilla instalada muy a proa o una cubierta como la de los porta-aviones con las superestructuras en un lado. En barcos pequenos de, por ejemplo, menos de 35 m, no se pueden adoptar estos cambios en las estructuras porque, ya para comenzar, las superficies disponibles en cubierta son demasiado pequeñas. Debido a ello, la boca del arte se tiene que llevar a la popa mientras se iza el copo. El pórtico basculante es una de las diversas maneras de lograr esta finalidad y ha resultado excelente en la práctica. El sistema unigan empleado en el *Universal Star* emplea este procedimiento. Estos pórticos se han montado en barcos hasta de 64 m de eslora y se han construido para otros de 15 m nada más. El funcionamiento del pórtico basculante mientras se cala o se recoge el arte se describe en esta comunicación, en la que también se examinan algunos problemas fundamentales relativos al proyecto y construcción de arrastreros con rampa a popa y se hacen sugerencias para soluçionarlos.

THIS paper describes some stern trawling developments in small trawlers which present quite different problems from those in larger ships. In all fishing vessels rising wages and operating costs throw emphasis upon crew economies and obtaining high utilisation. In larger ships, crew savings possible with stern trawling are not as important as with small ships and the predominant reasons for adopting stern trawling may be quite separate; for example, increased space in the ship for processing plant, increased trawling capacity, the difficulty of side fishing in large ships with considerable freeboard, etc. However, in small ships where perhaps three to fifteen men are carried, a saving of three or four men in say 130 ft (40 m) ships and one man in the smallest ships is of real economic importance.

Stern fishing allows a ship to fish in worse conditions, the ship being aligned better with the weather when shooting and hauling and the crew having much greater protection at all times. Furthermore, experience is that the hull design required for practical reasons in stern trawlers seems to produce ships with greater sea-keeping capacity than normal side trawlers with their low freeboard amidships. Moreover, the stern trawler with mechanized systems can handle gear more quickly and it is difficult to install comparable systems in a side trawler. As a result, because of better weather ability and quicker gear handling, the ship can actually fish for a longer time on a given voyage than can a side trawler. These arguments are particularly applicable to small ships ranging from say 40 down to 15 m. But there are difficulties in adopting stern fishing with these smaller ships which are not met with in bigger ones, due mainly to the inherently limited fore and aft length of the fishing deck and to sheer lack of space elsewhere.

Basic factors affecting stern fishing

However the gear is brought aboard over the stern, warps must be led forward. Big ships can use the net as an extension of the warps and haul the fish bag over the stern via a ramp, the whole net coming on board before the fish bag. Clearly this requires space, length in particular, and is not really possible with small ships, say under 130 ft (40 m) in length, unless the arrangement of the whole ship is subordinated to the requirement. A number of layouts have been proposed and indeed some have been built using cantilever deck houses with a tunnel leading to a forward winch installed at the break of the forecastle. Others have used compact high-speed machinery installed aft with side funnels and casings and the net hauled over the top of the engine room. Alternatively, it is possible to arrange the ship in aircraft carrier fashion with casings to one side and still more variations are possible, but generally all these arrangements lead to an awkward overall arrangement of a small ship.

If the engine room is forward, Fig. 1 shows a typical

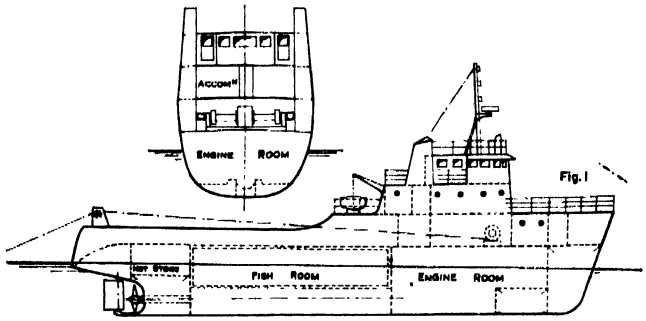

Fig. 1. See Text.

layout with cantilever deckhouses, while, if the engine room is arranged aft, Fig. 2 shows another typical arrangement. Again there must be cantilever deckhouses and the net and warps led between twin casings. An advantage is that the centre of pressure of lateral

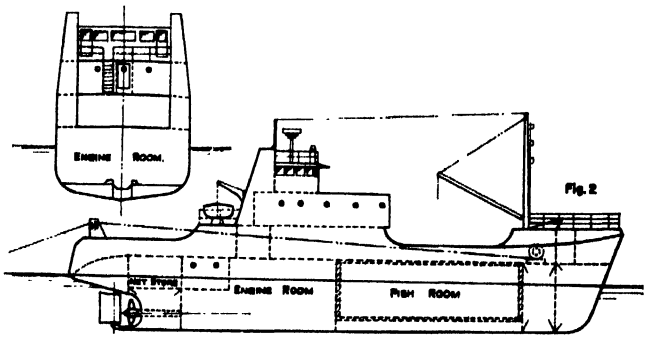

Fig. 2. See Text.

windage of the above-water profile is aft and this helps with handling problems but the arrangement is only possible if the machinery is of small height and hence of high revolutions and small volume.

A good example of this type of ship is shown in Fig. 3 which shows a recently constructed trawler. Here the main machinery consists of twin engines rated at 788 total continuous bhp at 1,400 engine rpm

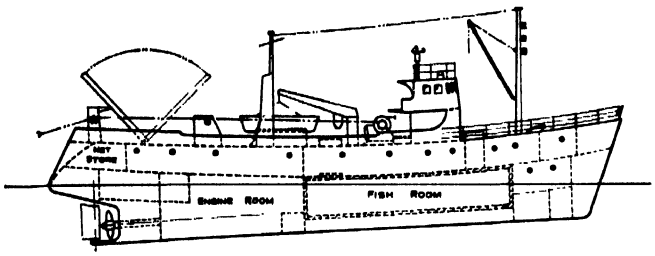

Fig. 3. Detail of newly built trawler.

geared together on to a constant speed controllable pitch screw with a constant speed trawl winch generator driven off the forward end of the gearbox. The arrangement is very convenient but, as mentioned, is dependent upon the use of rather specialised machinery.

Up to a point, the smaller the ship the more difficult is this problem but in very small ships which, anyway usually fit high-speed engines, the problem eases again as such engines go under the deck and it is not difficult to arrange exhausts and casings to suit.

The Unigan tiltable gantry solution was developed to avoid these difficulties, the concept being that during hauling only the mouth of the net should be brought over the stern and held there while the codend would be lifted on board over the stern. This has many advantages, being simple, quick and convenient, requiring a minimum of space and manpower and avoiding the length taken up by a ramp, although the inherent lack of space still poses some problems. For example, arrangements must be made for bringing the whole net on board for repairs but generally this can be handled by bringing the codend on board and leading it forward on strops from the trawl winch. Access to an underdeck net store, if fitted, can be a difficult minor problem.

The Unigan arrangement was first developed on the well-known *Universal Star*, has since been fitted to some twenty vessels and is being fitted to several others either ordered or under construction. Generally speaking, the system uses a strongly constructed hinging portal frame gallows from which the trawl warps are led and the gear towed. For example, in a 100-ft trawler where the warp breaking strain is 14 tons, the gantry will weigh approximately 1-1½ tons and will be designed to move a gilson block load of 1·5 tons, although much heavier loads can be handled by hauling in the codend with the gantry in an upright position. In the case of an extremely heavy catch it is sometimes desirable to bring the fish aboard in two or more operations. This double-bagging procedure is accompanied by tightening the half-bag becket by means of the gilson wire so splitting the catch. The codend is then brought aboard in the usual manner. After the fish have been deposited on the deck the codline is re-tied, the half-bag becket loosened and the codend returned to the water. The vessel is then given a kick ahead driving the remaining fish back into the codend which is then lifted aboard the vessel as before. Fig. 4 shows a typical outline arrangement of a Unigan trawler

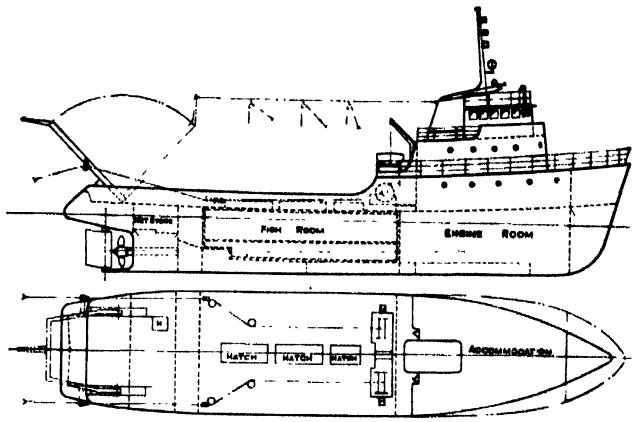

Fig. 4. Outline arrangement of Unigan trawler.

with the engine room forward and showing the lead of gear from the trawl winch.

The gear has been fitted in trawlers up to 210 ft (64 m) in length and has been developed for ships as small as 50 ft (15 m). However, the advantages of using the tiltable gantry vary with the size of the vessel. A net of considerable size can be handled with the gantry on a small but relatively powerful boat without difficulty, whereas such a net cannot be manhandled by a small crew. An example of such a net would be:

	ft in	m
Headline	63 0	19·0
Square	13 0	4·0
Baitings	25 0	7·5
Top wing	24 6	7·4
Lower wing	45 0	13·6
with a belly of	30 0	9·1

Indeed, in day fishing where gutting and heading is not carried out, such a boat of 50-55 ft (15-17 m) length and say 250 hp arranged with grouped propulsion steering, gantry and winch controls, etc., might be operated by two men in active trawling. The saving is considerable as a heavily designed vessel of this size with adequate power can be made equivalent in fishing ability to a normal side trawler of some 15-20 ft (4·5-6 m) greater length which may well have 6-7 men in its crew. One might say with some confidence that for approximately equal fishing capacity such ships can halve the number of crew often required by larger conventional vessels while, if registered under Part IV of the Merchant Shipping Act, they can be inside the 25 tons registered limit.

At the other end of the size range the main attraction is that the catch is lifted rather than dragged aboard. With a heavy bag the damage that may be inflicted on the catch by ramp trawlers when the codend is dragged

up the ramp is eliminated and this may be a factor in the value of the catch when destined for the normal white fish market. It would seem likely that a gantry which is really simply added to the normal ramp system will become more and more popular in such ships as, although derricks and cranes can carry out the same function, they cannot do it with the same efficiency and economy. The operation being primarily a transfer of weight fore and aft, it is best done with a system with only the one relevant degree of freedom. The gantry can be positioned to facilitate shooting the gear and also handling heavy gear such as trawl boards, etc. It must be remembered however that sometimes in ramp stern trawlers the quality of the catch is not a consideration, as it is understood that a number of large stern trawlers are fishing mainly for fishmeal production.

Factors in stern fishing vessel design

The design of small stern fishing trawlers offers many difficulties. Problems of accommodating the gear in the ship, especially are not simple and the hull design in itself needs to be sophisticated. Fundamentally the ship shoots and hauls her gear up-wind or down-wind. There are advantages, providing the weather is not too severe, in hauling down-wind as the gear streams naturally behind the vessel and little or no steerage way is required for the ship. This basic difference from the methods used in side trawlers is one of the factors responsible, of course, for the great improvement in the comfort and safety of the crew, commonly experienced with stern trawlers. However, if hauling headed into the wind, if the sea and wind are not in the same direction or there is a confused sea running, it may be difficult to prevent the ship's head blowing off. Furthermore, if a lone stern trawler is fishing in company with a number of side trawlers it may not be possible to shoot and haul before the wind and the ship may have to conform with the general trend, i.e., with the wind abeam. However, this is a temporary factor and the time will come when the odd side trawler will have to conform when fishing with stern trawlers. Ability to control the ship's head being critical, therefore, the ship must be designed with deep sections and good immersion aft.

The pitching centre must be as far aft as possible as otherwise, although the ship as a whole may be sea kindly and although the gear may fish very well, it may be impossible to handle gear on the aft deck or fantail due to its amplitude of motion. At the same time the bow must have good immersion and a hard forefoot in order to assist in preventing the ship's head blowing off and lowering the steering effort required to keep the ship on the intended course when hauling. As a result a large rake of keel is an anomaly, unlike side trawlers where it may be an advantage and necessary for steering when towing.

Windage forward, both in terms of area and drag coefficient, must be kept to a minimum for the same reasons generally speaking, therefore, the stern trawler will tend towards vessels of deep draft, low rake of keel, low block coefficient with a deeply immersed and hard forefoot profile with flat sections aft, carefully blended, however, into deep Vees to prevent slamming. If the pitching centre is far enough aft slamming does not occur with such sections, providing they are well immersed. Deckhouse and rigging detail, etc. must be as clean as possible and funnels avoided if the owners will permit this.

The stern must be so designed as to avoid entanglement of fishing with sterngear especially in the difficult stage of getting the codend on board. As a result it is desirable to fit the propeller and rudder well forward which is, of course, assisted by the low block coefficient inherent in stern trawlers.

Added protection for the propeller may be given by the fitting of a steering nozzle as has been done on the majority of the larger stern trawlers. Other advantages of a steering nozzle are an improvement in trawling pull, good steering capabilities at low speeds and the ability to use relatively high powers in conjunction with high rpm, without undue loss of efficiency. At the same time the introduction of a nozzle would appear to improve the pitching characteristics of the vessel. It is questionable whether the ideal layout of a stern trawler may not be obtained with twin screws as in the *Universal Star* but with engine rooms aft.

The twin screws naturally lend themselves to this type of layout as relatively small prime movers are inherent which may be installed aft and placed so that their casings are brought up the sides of the ship, leaving the fishing deck clear in between. There is much to be said for this layout which gives unequalled controllability in all phases of the shooting, trawling and hauling operation. It is not necessarily more expensive as, with half the power on each propeller, high-speed machinery in an altogether lighter range of engines may be used which, although they can be robust and conservatively stressed, are often cheap per horsepower and can offset the greater cost of steel and sterngear. Twin rudders are, however, a *sine qua non*, and a single rudder would be far from satisfactory. Prejudice against twin propeller propulsion does not seem reasonable in the case of stern trawlers though it may be for side trawlers.

Adequate ballast capacity is essential in a stern trawler, perhaps more so than with any side trawler. It is not enough to bring the stern down in order to give adequate immersion aft, because in such a case the draft at the bow may still be so light that it will blow off. Neither is it enough to bring the bow down far enough to give grip without ensuring at the same time that the stern is deep enough to bring the pitching centre suitably far aft. Fundamentally, a smallish stern trawler should be designed to be able to maintain substantially constant draft at all phases of her operations. This is not difficult to achieve.

Recent designs have shown that in most cases ballasting can keep the draft and trim within a few inches of the design target throughout all phases of the voyage. In this respect, an owner should not be allowed to dictate the quantity of ballast in such a ship. This is a delicate

matter falling inside the jurisdiction of the designer who should not allow himself to be deprived of the necessary space.

How Unigan operates

For shooting, the gantry is set up with the trawl laid out on the after deck, codend and body arranged over the stern ramp. Trawl boards are in a stowed position port and starboard, between the gantry legs and outer bulwarks. The boards are stowed in a fore and aft position just forward of the gantry pivot position and are attached to the outer bulwarks by short wire strops clipped to the forward edges of the boards.

The sweep wires are led from the winch under foot rollers at the base of the gantry and over the hanging blocks attached to the outboard sides of the gantry legs. The danleno bobbins and butterflies are attached to the sweep wires in the usual fashion and are lifted to the hanging blocks.

When ready to shoot the gantry is swung aft and the headline legs and towlegs are attached to the butterflies The codend is pushed over the stern and the drag from the water streams the net bellies after it. The quarter ropes are rove through special sheaves on the inside of the gantry legs and these, with the aid of the winch warping heads, are used to lift the footrope and heavy bobbins over the stern. In the case of light gear the drag from the net in the water is sufficient to stream the entire wings, footrope and headline over the specially shaped stern hump without manual effort.

This stern hump, or dwarf vee-shaped bulwark, is a recent innovation and supersedes the relatively more expensive hydraulically operated stern flap as fitted to the *Universal Star* and some subsequent vessels.

The stern hump gives added protection to the crew and facilitates the shooting and hauling of the gear.

With the entire net in the water, the warps are slacked until the strop links engage the Kelly eyes attached to the trawl board backstrops. At this point the gantry is swung forward and the warp slackened off. The G-link assembly can then be attached to the trawl boards, the warp taken in and the boards lifted to the hanging blocks. The strops holding the boards to the bulwarks can now be released and the gantry swung aft to allow them to drop clear of the stern when the winch brakes are released. The requisite amount of warp is let out in the usual manner.

The operation of hauling is in reverse sequence to that of shooting until the danleno bobbins are brought up to the hanging blocks. At this point the quarter ropes are detached from the butterflies and, by means of ropes rove through the gantry quarter sheaves, are used to bring the mouth of the net over the stern. A messenger rope, leading from the winch warping end and passing through a gilson block at the top of the gantry, is then attached to the pork line and the codend heaved up to the gilson block. The gantry can then be swung forward to deposit the fish in the deck ponds. The entire operation from the time the trawl boards break the water to depositing the fish on deck usually takes approximately 10 minutes.

Nothing, however, is static and in some cases it has been felt that towing from the gantry leads to an unduly heavy structure which in turn, of course, is reflected in the size and general cost of the hydraulic gear. An alternative arrangement has been produced. In this the gear is towed from gallow posts and the gantry is used to take the otterboards aft from the stowed position. Hanging blocks from the top of the gantry are used to lift the gear over the stern. As no towing and, in particular, no quartering loads come on the gantry it may be of much lighter construction, its design being governed only by the gilson block load. When the boards are brought up to the block on the gallows posts they are secured by dog chains, the G-link assembly unclipped from the board and the sweeps hauled in until the danlenos come up to the blocks (Fig. 5). This variation on the basic gear has

Fig. 5. A board brought up to the block on the gallows post.

worked well and is now afloat in two or three ships. It is not quite as flexible as the original *Universal Star* type gear but, on the other hand, performs well at a lower initial cost. The tiltable gantry gear may be modified without much difficulty to purse seining and a combination gear, which can stern trawl and purse seine without any fundamental alteration to the ship, is under

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Ross Daring—Experiment

Abstract

Ross Trawlers Limited are presently completing a 99-ft sterntrawler with a high degree of automation and extensive use of centralized controls. The vessel will have a 450 hp, 1,800 rpm engine situated aft and a fish-hold foreward of 4,800 ft³ capacity. Vessel, gear and crew are planned to cope with an average catch of one ton per day. The crew consists of skipper and four deckhands. All engine room functions, including servicing, bilge pumps, water supply, heating, etc, will be fully controlled from the bridge in the same manner as airplane engines are controlled and serviced from the cockpit. The vessel will operate a normal wing trawl which will be taken on deck over a stern roller. Hauling and shooting operations are fully mechanized and controlled by the skipper from the bridge with the exception of lifting the codend over the stern. A conventional sidetrawler of comparable size would need more than ten men on deck alone.

by

Dennis Roberts

Ross Trawlers Ltd.

L'Experience—Ross Daring

Résumé

La "Ross Trawlers Limited" achève actuellement un chalutier pêchant par l'arrière de 32 m qui aura un haut degré d'automation et sur lequel les contrôles seront centralisés. Le bateau équipé de machines de 450 cv, 1.800 tpm situées à l'arrière, a une cale d'une capacité de 135 m³. Le bateau, les engins et l'équipage sont prévus pour une capture moyenne de un tonne par jour. L'équipage est composé d'un patron de pêche et de quatre matelots. Toutes les fonctions des machines telles que: service, pompe de cale, distribution d'eau, chauffage, etc. seront entièrement contrôlées de la timonerie, de la même manière que les moteurs d'avion, contrôlés et alimentés de la cabine de pilotage. Les opérations de pêche s' effectueront avec un chalut à grande ouverture qui sera remonté par l'arrière, par-dessus un rouleau. Les opérations de chalutage, entièrement mécanisées, seront contrôlées par le patron depuis la timonerie à l'exception du relevage du sac. Pour un même travail, un chalutier traditionnel pêchant par le côté aura besoin de 10 hommes sur le pont.

Ross Daring—Un experimento

Extracto

Se completa para la empresa Ross Trawlers Ltd. un arrastrero para pescar por la popa de 99 pies de eslora muy automatizado y en el que se emplean mucho los mandos centralizados. Tendrá a popa un motor de 450 hp a 1.800 rpm situado y a proa una bodega de pescado de 4.800 pies cúbicos de capacidad. Está proyectado para pescar una tonelada diaria con una tripulación formada por el patrón y cuadro marineros. Todas las actividades de la sala de máquinas, incluídos engrase, accionamiento de las bombas de sentina, suministro de agua, calefacción etc., se controlarán desde el puente de la misma manera que los motores de un aeroplano se regulan y atienden desde la cabina. Tendrá el barco un arte de arrastre normal que se meterá a bordo sobre un rodillo colocado en la popa. Las maniobras de largar e izar son totalmente mecánicas y las hace el patrón desde el puente, excepción hecha del izado del saco sobre la popa. Un arrastrero que pescara por el costado de dimensiones análogas necesitaría más de 10 hombres en la cubierta.

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development. This must, however, use the normal Unigan as a basis.

Conclusions

The system described is one of several; nevertheless it is relatively widely adopted for small and medium-size trawlers. Initial teething troubles were not connected with the gear itself but arose from the differences in technique required in adapting from side to stern trawling and also from the twin screw arrangement of the *Universal Star*. In particular, headline breakages were traced to turning too sharply at the end of a steering leg and inadvertently collapsing the trawl. The extremely small turning circle of the *Universal Star* was largely responsible.

The ultimate, of course, in small stern trawler design is complete mechanization of fishing operation procedure allied to centralized engine control in the wheelhouse.

This has, to a fair extent, been accomplished by Unigan and further developments include an operating bay at the after end of the wheelhouse with grouped remote controls for gantry and winch. The reduction in crew due to the increased mechanization improves the economics of the operation and, at the same time, the better working conditions attract good grade fishermen, with a consequent increase in efficiency.

For Northern waters all gutting should be done under cover away from the elements and on even relatively small stern trawlers of say 100 ft (30 m) a shelter deck can be arranged to give this protection. This means that only one or two men are needed for a short time on the weather working deck during shooting and hauling.

Stern trawling has come to stay, and possibly the sole remaining barrier it has to break through is the reluctance of many owners to change over from their relatively new but technically obsolescent side trawlers to the more comfortable and safe stern trawlers that are now available. This is understandable and reasonable but the time is coming when the move has to be made. A development which may help is an arrangement for converting side trawlers into stern trawlers with a high degree of automation and crew protection at reasonable expense and without major structural alterations. This has been done on a trial ship which has proved successful and perhaps this development may form the transition phase generally needed. Certainly no one who has seen gear handled aboard a small stern trawler under difficult conditions can doubt that in the end the method will replace side trawling.

GREAT BRITAIN has already launched her first stern-trawler, employing automation, aimed to cut the cost of fishing. From Cochrane of Selby the vessel of 99 ft overall will be operating in the North Sea by October 1963. *Ross Daring* will be crewed by a skipper and four men.

The intention is to carry only enough men to handle the catch. If a vessel requires more men to work the gear than to handle the catch, then the design is wrong and it should not be followed.

Man or machine is the basic problem. Factories ashore have installed machines, whilst fishing vessels up to now have preserved the man. Each fishing community has a different problem, a different point of view, and it is impossible for all of us to move forward at the same pace and along the same lines of thought. One thing is certain . . . the more successful a community, the more conservative will be its thought, and the slower its development. We must be careful to avoid this lethargy, that is why automation in fishing has been so long delayed.

In recent years, fishermen have attained a higher standard of living and are enjoying more security, so much so that the younger men are not bothering to learn their job and hence are very expensive to carry. When men price themselves out of the market, the opportunity comes for the machine to replace the man.

This situation has already developed in the North Sea. Too many expensive men are employed working the ship, many more than are required to handle the catch. The fault lies in the design of the sidetrawler. Whatever manning scale is attempted, it is a fact that the conventional trawler requires one man for every 10 ft of length. If we can re-design to make this ratio 1 to 20, then something useful will have been achieved.

Catching capacity

A trawler's capability should not be judged by the number of men aboard but by overall length. The minimum length required to operate in the North Sea all the year round is thought to be 99 ft. This length of vessel is capable of catching an average of approximately one ton of fish per day; therefore the crew should be no more than the number required to handle the catch comfortably —and that is the skipper with four good fishermen.

It is acknowledged that there are sidetrawlers employing only this number of men, but they are very small vessels pulling a very light gear. The size of gear suitable for a 99 ft vessel requires ten men to handle if operated from the side on a conventional trawler.

As half this number only is being employed, then the sterntrawler must have a high degree of automation to simplify the work for these men.

The point can be made here that it is not necessary to go to sterntrawling in the North Sea if the crew numbers are not being reduced accordingly.

Are engineers necessary?

The managing director, travelling in his luxury car, does not have a mechanic on the back seat. Then why should a fairly elementary diesel engine of this vessel have two unproductive men to watch it hour by hour? It is nonsense to say it must be so, in a year when men are being rocketted into space! It has not happened before because there has been no demand for such an engine. It will be commonplace in five years' time. Control of engines, services, bilge pumps, water supply, heating, etc., all can be exercised from the bridge.

Integrated control

Control of winches must be integrated with all relevant information obtained from bridge instruments. At some point, whether bottom or midwater trawling, the speed of tow must be adjusted, the length of warp altered, perhaps the angle of inclination of trawl doors. It is quite wrong that the control of the winch is on the deck and that a man must don oilskins and get wet every time the skipper requires a warp adjustment. This is the

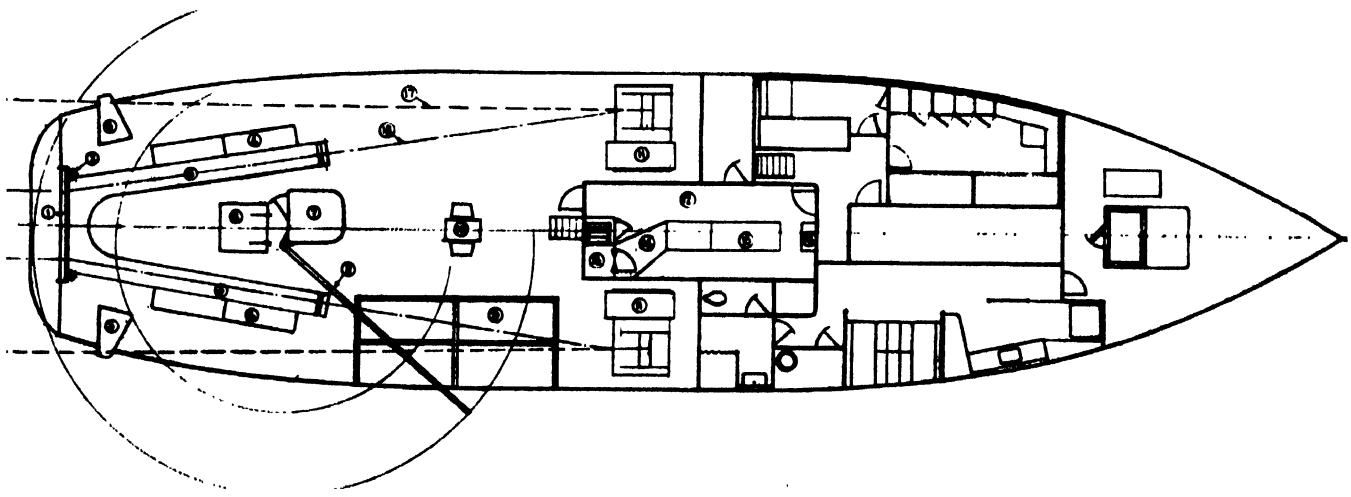

Fig. 1. Single-screw steel motor sterntrawler for operation in the North Sea area. Dimensions: 85 ft LBP × 23 ft Bmld × 12 ft 6 in Bmld. KEY: 1. Stern roller. 2. Guide rollers, P. & S. 3. Bobbin trays. 4. Steps to bobbin trays. 5. Gallows, P. & S. 6. Hatch to bobbin store. 7. Mast house. 8. Derrick. 9. Fish pounds. 10. Warping winch. 11. Trawl winch, P. & S. 12. Gutting room. 13. Tray. 14. Gutting trough. 15. Washing trough. 16. Chute to fishroom. 17. Trawl lead. 18. Bobbin lead.

point where automation does the fisherman a real service. It is now a fact that the skipper can bring the trawl doors up into the gallows by the touch of a button.

Will fishermen accept these exciting new vessels? Yes, certainly. Very few labour-saving devices have been introduced into the working of the trawl; those that have, have indeed been welcomed. It is the aim to improve the standard of living of fishermen still further. Five good men sharing £7,000 are better off than ten sharing £10,000 (these figures are an example and not a proposal).

Fishing gear

The economics of this vessel have been worked out on using traditional trawls. If there is an improved method of catching fish, then it will be welcomed. Research into improving trawls is going on and, until something more useful is developed, a wing trawl will be used.

Unlike many stern trawlers, the *Ross Daring* has no stern chute because of the risk of swamping the fishing deck in winter conditions. The gear is taken over a wide roller across the transom and the bobbins are contained on a sloping tray or trough. Codends are taken over the quarter, as with Canadian stern draggers.

Both port and starboard winches are hydraulic and controlled from the bridge, so the skipper is able to bring the wings up to the winches and the bobbins on to the tray. Control is then taken over locally by the deck crew who have a small hydraulic capstan employing two whipping drums, mounted centrally, to swing-in the codends, etc.

The fish is sorted and shot into the gutting and washing house. From there, after processing, it is transported forward down a chute into the fish-room where it is packed away in ice in the traditional manner. The fish-room is forward and has a capacity of 4,800 ft^3. Hatches are only removed for unloading.

The engine room is conveniently situated beneath the fishing deck and astern of the fish-hold. The engine is a Ruston Paxman 8 R.P.H.C.M. 450 shp at 1,200 rpm.

The experience obtained from *Ross Daring* compared with that from the new American sterntrawler *Narragansett* will be awaited with great interest. From these enterprises the development of commercial fisheries moves forward into the enlightened age of automation. The sooner we see the end of fishermen slogging away on an open deck, the better.

Discussion on Stern Trawling

Mr. Robert F. Allen (USA) rapporteur: Since the last FAO Fishing Gear Congress, the principle of stern trawling has been applied on vessels large and small throughout the world. The basic principle has now been accepted and the papers this year deal with the refinements and mechanization of the system. Mr. Birkhoff has summarized the various types of sterntrawler designs in use today, classifying them as factory ships, deep sea trawlers or smaller vessels. Further distinction is made in the deck arrangement and the location of the navigational bridge. Of particular interest in the three papers presented this year on trawling are the deck arrangements and the handling gear for small coastal vessels. Both Mr. Corlett and Mr. Birkhoff describe the use of the tiltable or turntable gantry to extend the effective working deck area of the vessel. Mr. Dennis Roberts' new vessel, *The Ross Daring*, will however use a system of lifting the cod end with a boom similar to that used on the Canadian and American Pacific Coast system. A similar attempt at designing and building a small mechanized trawler has been accomplished in the United States. This vessel, the *Narragansett*, has a stern ramp and employs a large drum for winding on the wings so as to minimize the requirement for deck space.

A designer who is contemplating a new sterntrawler could do well to review the considerations of sterntrawler design that Mr. Corlett has proposed. Since the vessel is only part of the fishing system, considerations should also be given to the design of the gear to be hauled. Mr. Birkhoff, in his paper, suggests some modifications which have been made to the trawl nets which have been found of advantage in stern trawling. This is a subject in itself and should be discussed at greater length.

The subject of automation and centralized control, although applied to all vessels, is extremely important in stern trawling. Mr. Roberts hopes to reduce his complement on the *Ross Daring* to five. A great effort has also been made on the *Narragansett* to automate the deck machinery and to centralize the control in the pilot house. This should also reduce the complement to a bare minimum. Commander Pain's paper suggests that not only the operational functions, but the maintenance functions of caring for the vessel's machinery can be accomplished from the bridge, thus wholly eliminating the necessity for engineers on the vessel. It would be appropriate to hear from the participants about their experiences on automation, as we all know that it is the emergencies rather than the normal operations which will ultimately determine the extent to which men can be eliminated from the vessel.

Dr. I. H. Heinsohn (Germany): My firm has built some fifteen stern trawlers of medium size operating in Northern waters for Germany, Norwegian and British owners. They are mainly from 180 ft bp up to 220 ft and they work mainly on wet fish. The latest are small service factory vessels. Referring to Corlett's paper on the Unigan System he endorsed most of the points, but he would point out in relation to the gantry that the old fairy tale was repeated that fish hauled over the ramp suffered damage. This was sheer nonsense. In contrast it would be impossible, in the case of heavy fishing, to lift thirty tons of fish by the gantry and in that case what would happen to the fish at the bottom, with 30 tons of fish on top of it? Every practical consideration was against the allegation of damage and every trawler operator would agree to that.

He also could not agree that the Unigan gantry was better and quicker than the ramp. This was true only in the case of very small trawlers. In most fisheries, trawling caused damage to the nets and when they were damaged they required space for laying out and repair so that it was always better to stretch the net out; therefore, even on smaller vessels, emphasis should be laid on the need for giving as much space as possible. Still, he agreed that for very small vessels the

gantry was worth its money but on bigger vessels it was not.

He congratulated the Ross Daring experiment as it was really promising for near-water fishing. They had to save man power and every mechanical device should be tried to work with fewer men.

On the bigger trawlers much could be said for twin screws, if they were properly designed—that is with big propellers. They gave better efficiency when towing and also gave more reserve power which should be of advantage when shooting complicated gear. If, however, twin screws were installed there should be also twin rudders. A single rudder was no good with twin screws and slowed trawling speeds.

Birkhoff's paper raised the question of mechanization as did other papers. On this point he had to pour some water into the wine. On paper, everything worked very well but as soon as the skipper had fouled gear, you had to start working by hand or, if the warp had parted you had to make the gear ready again and that meant hard manual work. Mechanical devices were normally installed for performing any one purpose. They could not be very flexible so that if anything happened out of the scope of the design you are in trouble. On this point he had worked out just what an ordinary trawler would require in the way of full mechanization. To adequately handle all the needs of shooting and hauling a net on a big sterntrawler at least seven winches would be needed besides the trawl winch. Each winch should have a hauling power of between one and three tons depending on the size of the net. Such winches cost anything between £300 and £1,000 so you could easily run up to anything between £5,000 or £6,000 for winches. The question is whether it is worthwhile? Even if you have mechanized your system, in the case of fouling gear you have still to work something on the warp drums and you must, in any case have a few men.

Further, a few men must be on board to operate the mechanized equipment. He suggested that you could not work with less than two men on each gallows which makes four, one man supervising them, and at least one man in control of the winches and supervising all the gadgets. If they had so many winches and gadgets to operate it could easily lead to a mishap and involve accidents. So, at least under German law, he had some doubt whether full mechanization would be allowed, because control could easily get out of hand: in any case somebody had to watch and if anybody got caught in the wire, he could be drawn into the drum and a severe accident happen.

On the other hand the normal practice was for the men handling the gear to do gutting as well; therefore he could not see that, with big gear, they could get down to only two or three men by mechanization. To haul the gear only by mechanical means on a big vessel they would need a slipdeck of from 30 to 40 metres in length and with the hauling winch placed as far forward as possible. To prevent the danlenos and bobbins rolling and banging about under the weather conditions of the Northern waters, there would have to be preventive structures together with a trolley way running along the coaming—little as he liked that idea. With the headline being shorter than the footrope, there would have to be a U-shaped guard to control the bobbins. All these points needed consideration if full mechanization was being contemplated.

If the gear became fast on the ground, a side trawler was better able to manoeuvre free than a stern trawler as it could swing and go over the gear more quickly. Quick changes, of course, were sometimes necessary for various reasons and, therefore, emphasis should be laid on the need for the aft trawl blocks being able to allow the warps up to 90 per cent horizontal clearance on each side without fouling elsewhere. The shape of the stern and the position of the stern blocks demanded care in guarding the trawl boards from swinging and banging. These, again, would require moving devices and one strong recommendation to all designers was to eliminate as much as possible everything that moved because they involved attention and maintenance. All of these things gave food for further thought. We should not keep our heads in the clouds too high regarding mechanization, automation and so on. It was necessary to keep your feet on the ground.

Mr. W. W. Carlson (USA): My company are the builders and operators of the *Narragansett* and other vessels. If we ever heard of all the problems referred to by the last speaker we would probably have been afraid to build that vessel. However, in our ignorance, we went ahead and built it and have operated it very successfully. We do not have seven winches and we operate everything from the pilot house; two men on deck with reasonable intelligence had no trouble in getting the net over and getting it back. I am no fisherman and I have done it myself. We operate quite well, do not tear our nets and have reasonably good catches. The boat has been really successful.

Mr. Harper Gow: Your point is that automation on your vessel can be achieved with much less equipment than would be required on larger vessels.

Mr. D. L. Alverson (USA): There is a difference between stern trawling and stern ramp trawling. Simple stern trawling came from the Mediterranean and has been practised in the U.S.A. since the inception of trawling there. But stern ramp trawling has only recently developed. On the Pacific Coast 80 ft to 130 ft vessels have worked and continue to work successfully with four men and sometimes only three men aboard. Some of their trips range up to 20 days in length. One vessel of 140 ft has only four men. This is a matter in which historic development has to be recognised and the psychology of the fishermen themselves; you must also consider the economics involved and how the catch is shared among the fishermen. Our West Coast trawlers have changed somewhat in the last four years. Most of the vessels now use a drum and roll on the net; this is very close to the stern and when the codend is reached it is swung round on the small gantry and lifted over on the side of the vessel. The *Narragansett* has a small ramp to bring the codend right up into the vessel.

Mr. Conrad Birkhoff (Germany): As a naval architect I agree with the views of Corlett and Roberts that the use of the ramp in small ships has limits. Under certain conditions this ramp is not absolutely necessary and sometimes not even possible. But the conditions of today might alter and open possibilities for later use. It has been proved that well constructed ramps do not cause any damage to fish and that hauling big catches up the ramp saved much time. He thought, therefore, they should always, if possible, consider the construction of a ramp which permitted hauling the gear as far as the gallows and, when necessary, made it possible to haul the entire trawl gear onto the deck for mending or servicing.

The codend suffered less by sliding over the ramp than by almost vertical hoisting which might involve a swinging of the bag in rough seas. This idea was involved in Corlett's

new bulwark form. He thought, however, that the hauling during the different phases of the gantry movements could easily be accomplished by a combination of two blocks on a fixed framework formed by a bipod post with gallow consoles at the posts and an outrigger codend derrick aft. This construction would be cheaper and more robust for being fixed. The recently developed gantry nose had the same function as the codend derrick before but involved some additional costs.

He was not, however, against the idea of a tiltable gantry but it should be contemplated in relation to total building costs. He recommended, at any rate, a fixed construction of gallows which was alluded to as an innovation in Corlett's paper. It would be a further step ahead if the gallows were built so that the trawl doors could be located close to the gallow posts. It might then also be possible to exclude from the tasks of the gantry the hauling of the codend by building a normal fixed bipod post. For the remaining tasks during the shooting operations such as moving the codend (and possibly the quarter ropes) and facilitating the shooting in the case of the bobbin gear hoisted on deck, a bipod outrigger derrick leading from the gallow consoles would then be the lightest, cleanest and most adequate solution. Such a gantry would be useful for accomplishing these various tasks and last but not least for the alternative employment of the ship in different fishing methods. For the normal trawl fishery he could, however, see no reason why the fixed gallows should be abandoned.

Corlett's arguments on the necessity of the lateral underwater and above-water area of the ship should be underlined. Those ideas were conclusive in relation to the bulbous bows for this type of vessel and they reduced pitching.

Automation of the remaining phases of handling the net was more possible on bigger ships than little ones. But the relative economy of a reduced crew was of greater importance on smaller vessels so that due regard should be given to the idea especially for such vessels. Mr. Roberts' paper showed that the technical ideas had been well adapted to small vessels in rough seas. The possibilities of a bobbin track for various bobbin gears without imposing restrictions on further gear should be contemplated in detail. The swinging of the codend over the side near the propeller might be dangerous in rough seas because of movement in that area.

His view was that the basic character of trawl gear had remained unchanged for years and had not even been affected considerably by pelagic nets. But we should be able to cope with all these assumptions in coming years. He therefore suggested the automatic positioning of the trawl doors which did not need pennants any more, if the further hauling of the net could be done by counter pulling the sweeplines by means of gillson blocks. Apart from the question of the crew required for gutting, the most dangerous part of the work would then be done automatically—even when the gear became bigger and heavier in the future. If improved gutting machines did become available in the future then a big saving of crew would be achieved.

Mr. Dennis Roberts (UK): I had hoped some speakers would criticise the Ross Daring plan but most speakers had welcomed it. Dr. Heinsohn had advised them to keep their feet on the ground. He would say that he was a practical fisherman with 25 years experience at sea. It had always been his dream to build a trawler so simply handled that he could take his wife and children with him and go out and fish. He was very pleased to learn about the *Narragansett*. The big difference between that vessel and the *Ross Daring* was that the *Ross Daring* took their gear over a transom stern. When he had visited the Canadian Pacific Coast and saw their vessels, the fishermen told him they did not think their type of vessel was suitable for fishing in the North Sea. He thought a 100 ft vessel with a ramp working in winds of force 7 or 8 would be swamped. A transom stern would be much safer. A lot of his ideas were based on experience with 60 ft Canadian vessels.

Mr. E. C. B. Corlett (UK): The gantry system is essentially for smaller trawlers and he had been surprised that it had been used in Germany on some of their large trawlers. He was very interested in designing small vessels and the plan of the *Ross Daring* impressed him very much and he wished Mr. Roberts good luck. If, however, he caught more than one ton of fish per day he might find difficulty in handling it. If he caught ten tons a day he would be in difficulties. His firm had recently designed and completed a trawler almost identical in size—length 91 ft, beam 23 ft, depth 12 ft 3 in., and draught aft under 10 ft—almost identical—it carried 12 crew and was also highly automated. It was fishing in the rough waters north of Norway and was catching ten tons of fish per day, every day. Three or four men simply could not cope in those conditions with catches of that size.

On the question of the gantry it had to be built and stressed so that it would take a full drawing load up to 90 degrees off the towing line. It was expensive to provide that, but, in fact, by far the biggest load on the gantry came under those conditions. That was the reason for adopting the simpler arrangement for towing from the gallows post. This system worked very well, although it did have a slight disadvantage for handling the boards. It was also a good deal cheaper and the gantry could be built lighter and the hydraulics involved were less expensive. Mr. Roberts had made a good point regarding the ramp on smaller trawlers. It was most important they should have sufficient buoyancy and protection for the men. The smaller trawler he had mentioned had very powerful split winches—seven tons pull each. Fixed gantries were more or less standard practice on larger trawlers but on smaller trawlers they provided a good deal of windage and iced up in the Arctic. Remotely controlled winches were interesting possibilities. They had provided one which was worked by an operator who had a whole deckhouse between himself and the winch. He had been very sceptical about this at first but it did work very well. Remote control of winches did help the design of stern trawlers a great deal and he thought the practice would spread even if full automation was not possible.

Mr. C. Maurin (France): We have had experience of a gantry based on a German patent. The system originally used turned out to be fairly difficult particularly so far as handling the trawl boards was concerned. The hauling was fairly difficult and use of the gantry in heavy seas was dangerous. The catwalk for supervising the hauling was too close to the sea and in heavy seas created some risk. An alteration was made whereby the catwalk was raised. This made it possible to bring the trawl boards in quite easily. Finally the system was improved by bringing the wings in up to the level of the winch which meant that the central part of the trawl could be brought up to the deck directly. At times the trawl came on to the deck in heavy seas and there was risk from movement. In later French ships the net has been wedged alongside the deckhouse. The disadvantages arose from heavy seas. On the *Tallinn* an active rudder was used which meant that they could manoeuvre better in a current. This

active steering required a strong motor for working it. In the case of fouling it was easier to get clear on a side trawler but in a stern trawler there was available far greater speed in manoeuvring and speed in handling and with the modification made, the size of the crew could be cut down compared with a side trawler. On a stern trawler men had greater protection. So far as damage to the fish being concerned because of the slope of the ramp, he had never observed any damage of this kind. On the contrary, he found that the fish came in very good condition. Another advantage was that where fishing was done in calm waters and without wind the trawl when shot from a stern trawler, went deep into the water. In a side trawler the trawl sometimes went down incorrectly and there was a risk of trawl boards crossing, but working from a stern trawler that difficulty was overcome. The *Tallinn*, with the alterations now made, was proving very satisfactory. They now had working from Lorient two medium tonnage ships working with a gantry system and the owners of those ships could give a very satisfactory account of their results.

Mr. F. Dorville (France): The two vessels referred to have a sheltered control deck and the Unigan System does give the advantages described. By its use you can place the whole of the trawl in a very good position for strapping, backing and also bringing in the trawl boards without danger. The crews work under better conditions. We did have some small difficulties in the first place when the boat was rolling and this resulted in the bag swinging about but this was overcome by a fairly simple operation in placing two legs between the gantry which cut down the swinging as the bag came aboard. I can confirm that these two ships are operating very successfully. We can thus say that the Unigan system, because of its simplicity and automation and concentration on the stern of the ship, can be applied on various types of ships. We had two trawlers with covered sterns. Another has a working area in the bow and there is a conveyor which brings the fish forward to the working area. Both on the 15 to 20 or 45 to 50 metre length of craft that we have, the system is very flexible and at the same time gives very useful mechanization which takes a lot of work off the crew.

Mr. Jean Frechet (Canada): Over the last three years Canada has been very active in investigating the best trawler design for small craft and their mechanization. They considered stern trawling was still in its infancy and many problems had still to be overcome. One related to the multiplicity of designs for operating the trawl over the stern. They felt that stern trawling should be fully operative over the stern and that the deck layout and equipment should relate to that. These problems would be solved over the next decade. With a view to that end, some small trawlers had been built and would be followed by others so that they could learn by experience and their mistakes should not be too big. They now felt safe in going further forward.

Dr. G. C. Trout (UK): For investigations at Lowestoft we are considering a small trawler of some 35 metres in length. After his trip on the *Fairtry* he had been so impressed by the quality of the fish that they considered going in for a stern ramp although the vessel was of such small length. He would like more information about the freeboard. He understood the *Universal Star* had a very low freeboard and it might be that that resulted in her being a wet ship and therefore on consideration he would not advocate a ramp. Mr. Birkhoff's design, although not yet built, had a freeboard of about three metres or more and that might be why there was no unanimity of opinion about a stern ramp in a small ship. He was extremely heartened to see the design of the *Narragansett* which looked a delightful ship and he was glad to know it worked well.

Mr. D. J. Doust (UK): The papers presented by Birkhoff Corlett and Roberts are of particular interest, since they show the interdependence of the fishing gear and handling problems with the requirements of good design. For economic success, the design of vessels for a particular type of fishing must properly be those in which all the essential technical factors are fully integrated. What sometimes appears to be an advantageous innovation from one point of view, may, however, incur another more serious disadvantage resulting in an overall loss of earning capacity, or even complete failure. This factor is clearly brought out in Corlett's discussion of the design requirements of smaller stern-fishing vessels which require a pitching axis well aft of amidships to avoid excessive stern motions and accelerations. Failure to provide for this feature of the design nullifies the advantages of stern-fishing and improved fishing gear, purely on account of the physical inability of the personnel to use the new techniques in adverse weather conditions.

With the transition from side to stern trawling and the attendant multiplicity of internal and deck arrangements, more attention has to be given to this requirement of minimum motion and acceleration at the stern. Machinery and gear-handling layouts which favour such a stern trawler design are more likely to become economically successful, mainly due to their ability to make more use of the time spent on the fishing grounds. From the point of view of the vessel's hull shape, the type of transverse sections which can be incorporated in such designs is largely governed by the relative positions of engine and fish rooms. Diesel-electric machinery for the larger deep-sea trawlers would seem to offer the maximum flexibility in this respect, since the full amidships portion of the hull can be utilised to store the catch, thus minimizing the problem of change of trim with increasing fish load as the voyage progresses.

The requirement of minimum motion of the stern generally favours an asymmetric hull shape, with an LCB position about 4 per cent aft of amidships BP, although there are possibly further advantages if the LCB position could be moved even further aft. Vessels with machinery aft, as shown in Birkhoff's figures 3, 4, 5 and 6, and Corlett's figures 2 and 3, rather lend themselves to the more favourable hull shapes on this account, although somewhat increasing the fish-handling problems on board with the forward fish rooms. There would, however, on balance, appear to be more favourable overall design characteristics for the smaller stern trawlers, by adopting an aft position of engine room, with the fish rooms below the working deck amidships.

Mr. W. Dickson (UK): The development of stern trawling raises the question of the types of nets required by them. The separate winches used for the sweeplines make it much easier to haul double or triple lines and he did not see why they should necessarily have danlenos or bobbins. Provided the sweeps were fairly long, once the doors were disconnected, the double wire could be hauled to the sweep wire winch. Regarding Mr. Alverson's comment about winding the net on the drum, they could not get the whole trawl onto the drum because of the heavy ground ropes but it might be possible to get up to say 20 feet of the wings and that would save 20 feet of working deck. It was not really necessary to use kites and all those complicated things that could go

wrong when shooting from the stern.

Did anyone really have evidence that those kites did scare the fish down into the net? In the absence of that, they might just as well get the headline height by re-designing the net. There was also the possibility of easier handling of the trawl boards because the shooting was straightforward. One could then go in for more refinement in the doors and be surer that they would go away all square than with side trawlers. They thus had the option of securing greater headline height and greater spread and even a bit of both. One usually had to pay for those advantages by either increased damage or increased drag. For practical purposes they had to choose. They could go to sea with two or three different nets suitable for fishing but not more. At the moment they did not really know how much headline height was best. For design purposes they had to have a figure: 12 or 15 feet and that height would be determined by what they could find out about fish behaviour. There were two approaches to this: (1) either direct observation by camera, TV, netzsonde equipment or observation by submarine and that was a task for research workers; (2) the other way was just to try it and see: make a net and compare it with a standard Granton trawl. To do this one must have accurate measurements on the fish caught, haul by haul, and measure at least a decent sample. Some of this could be done by research vessels but it would be a great mistake to think it could all be done by them. There should be more co-operation between commercial craft in the industry and the research workers in doing that work.

Asked by Mr. Harper Gow for a clearer view because he, (Mr. Gow), had the impression that the higher the net the better, Mr. Dickson said: I do not know the real answer. There is not much doubt that if you make a net bigger you are likely to catch more fish but do you make it by bigger height or by shaping and spreading the net? The bigger you make the headline height the more you cut down the spread. You have to look at the height of the fish off the bottom and ascertain their concentration and do this at different times of the year and design a net to suit average conditions the year round—what proportions go into the height, what into the spread and what the taper should be. If you have a high headline you have to have a big taper. You must work out the average for a reasonable headline height for the whole year.

Mr. Robert F. Allen (rapporteur) summing up said: There still seems to be many differences in the net handling methods on large European trawlers and the discussion has reflected these differences. Strong opinions were expressed by three of the delegates that experience shows a ramp does not damage the fish if properly designed. This seems to be a rather conclusive result. There is still discussion, however, and differences of opinion on the method of hoisting the codend and positioning the trawl bag. The minimum deck space available on smaller vessels is a determining factor in designing the gear for hoisting the codend aboard. Ramps for this type of vessel are not generally considered practical because of the loss in deck space and the hazard of taking sea on board. Freeboard is a big consideration in the seaworthiness of a ramp design, but this particular problem is more acute on the smaller vessels where freeboard is limited.

Although the aim of designers is full automation of the fishing operation, a major deterrent in achieving this end is the extenuating circumstances which are encountered when the gear is stuck or ripped, or when unusually large catches are encountered. Mr. Corlett has pointed out that there is a great difference in the number of men required on an automated vessel catching one ton per day compared with vessels catching ten tons per day. This would indicate that great strides could be made in reducing crew if automatic machines were available to process the larger catches.

In consideration of the comfort of the crew and the safety to the fishermen, Mr. Doust's comments on hull form with regard to pitching should be well noted by naval architects.

Lest we forget that the fish are still caught in the nets, Mr. Dickson reminds us that more experiments are indeed necessary to provide the most effective gear and to this end let us strive for more co-operation between commercial craft in the industry and the research workers

Some of the General Engineering Principles of Trawl Gear Design

Abstract
In 1959 the White Fish Authority, with financial support from the British Trawlers' Federation and H.M. Government, through contract, began an extended investigation to develop a distant water trawl having as its specific features: (a) increased headline height; (b) increased netmouth width; (c) sound structural design and (d) improvement in handling. This paper reports on the hydrodynamic studies which formed a part of this project and is well illustrated with some 39 figures. Details of experiments, special equipment used, observations and results concerning the behaviour of the warps, otter board forces and moments, otter board stability, width and height of the mouth of the net, and drag of the net are given. A set of approximate equations from which warp curvature can be estimated with sufficient accuracy was developed. It was found that when measurements of ship speed and engine r.p.m. are available, a value of towing pull can readily be deduced. Experiments indicated that aerofoil type forces can be determined from measurements of a model in a wind tunnel, a ground being placed adjacent to the otter board to represent the seabed. The quantities measured are side-force, drag, lift, pitching moment and yawing moment. A method was developed for calculating headline height from a knowledge of the characteristics of the headline lifters and other factors. The author believes the objectives set forth were accomplished and that a basic theory has been provided from which gears can be designed to meet certain specifications. He also states that close co-ordination between gear engineering design and fish behaviour projects is necessary.

Quelques principes du genie maritime concernant le dessin de chalut
Résumé
En 1959, la "White Fish Authority" travaillant sous contrat, avec l'aide financière de la "British Trawlers' Federation" et du Gouvernement, a commencé une investigation poussée, pour le développement des chaluts hauturiers. Les buts de cette recherche étaient: (a) acroître la hauteur de l'ouverture verticale; (b) accroître l'ouverture du filet; (c) établir des principes de base de construction et (d) améliorer l'opération de l'engin. La communication décrit les études hydrodynamiques qui ont constitué une partie de ce projet et contient 39 illustrations. Sont donnés également, des détails sur les épreuves, l'équipement spécial utilisé, les observations et résulta obtenus concernant la configuration des funes, les mouvements et forces des panneaux, leur stabilité, l'ouverture horizontale et verticale du filet et la résistance à la traîne de l'engin. Des équations approximatives ont été développées à partir desquelles on peut estimer avec assez de précision la courbure des funes pendant l'opération. Il a été trouvé que, lorsque la vitesse dans l'eau et les tpm de la machine sont connus, la valeur de la force de touage peut être facilement calculée. Les expériences ont indiqué que les forces de type aérodynamique, peuvent être déterminées par des mesures effectuées sur un modèle dans un tunnel aérodynamique, lorsqu'on a pris soin de placer un fond près du panneau de chalut pour représenter le fond de la mer. Les valeurs mesurées pendant les expériences étaient: force latérale, résistance à la traîne, force d'élévation, importance du tangage et importance d'embardage. Une méthode fut développée pour calculer l'ouverture verticale à partir de la connaissance des caractéristiques des élévateurs et autres facteurs. L'auteur croit que les objectifs ont été atteints, qu'une théorie de base a été développée et permettra de dessiner des engins pouvant satisfaire certaines conditions spécifiques. Une coordination étroite entre le dessin technique des engins et les projets de comportement du poisson est nécessaire.

Principios de mecanica general de las formas del arte de arrastre
Extracto
En 1959 la White Fish Authority, con la ayuda financiera de gobierno y de la Federación de Armadores de Arrastreros de la Gran Bretaña, inició una amplia investigación para encontrar un arte de arrastre para la pesca de gran altura que tuviera como caracteristicas específicas: (a) mayor altura de la relinga de corchos; (b) mayor abertura horizontal; (c) buenas formas estructurales, y (d) más facilidad de manipulación. Esta comunicación da cuenta de los estudios que formaron parte de este proyecto. Está muy bien ilustrada con 39 figs. Se dan detalles de los experimentos, el material especial empleado, observaciones y resultados relativos al comportamiento de los cables, fuerzas, movimientos y estabilidad de las puertas, altura y anchura de la boca y resistencia de la red. Se encontraron ecuaciones aproximadas con las cuales la curvatura del cable puede estimarse con exactitud suficiente. Se observó que cuando se conocen la velocidad del barco y las r.p.m. del motor se puede deducir fácilmente el valor del tiro de remolque. Los experimentos indican que las fuerzas de tipo aerodinámico pueden determinarse a partir de medidas de un modelo en un túnel de viento, colocándose un suelo junto a la puerta para representar el fondo del mar. Los valores medidos son: fuerza lateral, arrastre, fuerza ascensional, momento de cabeceo y momento de guiñada. Se encontró un procedimiento para calcular la altura de la relinga de corchos basándose en el conocimiento de las características de sus elevadores y do otros factores. El autor cree que se alcanzaron las finalidades propuestas y que se ha formulado una teoría fundamental con la cual se pueden proyectar artes que satisfagan determinadas especificaciones. Afirma que es necesario coordinar los aspectos mecánicos de las formas de los artes y los proyectos de comportamiento de los peces.

by
P. R. Crewe

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1. FIRMS that engage in aircraft design almost always have aerodynamics departments, and wind tunnels for testing models. These departments are concerned with the airflow round the craft and the way it affects powering requirements, stability and other such behaviour. One difference between the Westland Aircraft Company and other British aircraft contractors is, however, that its Saunders-Roe Division also has a hydrodynamics department, and towing tanks. These undertake corresponding work with regard to craft and equipment that move on or through the water. In recent years they have made a number of special investigations in connection, for example, with a large cargo submarine, yachts and, currently, trawl gear.

Trawl gear work commenced at Saunders-Roe with limited investigations for one or two firms, and in particular for the Lord Line Company, Hull. In 1959 the White Fish Authority, with financial support from the British Trawlers' Federation and H.M. Government,

gave a contract for an extended investigation leading to the development of a distant-water trawl having as its specified features:

(a) Increased headline height.
(b) Increased net mouth width.
(c) Sound structural design.
(d) Improvement in handling.

These are purely engineering objectives, which could be achieved without reference to problems of fish behaviour, and consideration of the latter was not required. However the available information on fish reactions was borne in mind. This in the main comprised two observations:

(i) The practical experience of the industry that catch is increased as the otter boards are moved further and further ahead of the net, using long sweeplines or legs.
(ii) Indications of fisheries laboratory experiments that fish do not appear to react to gear until it is extremely close to them, unless they can see it.

The present paper seeks to demonstrate that the Company's know-how and facilities in hydrodynamics, model testing, structural engineering, instrumentation design and electronic equipment have proved most suitable for establishing or confirming the general engineering principles on which good trawl gear design depends and for designing the trawl gear specified.

2. GENERAL PROBLEMS

Consider the schematic trawl gear shown in Fig. 1. Logically one should perhaps start with the behaviour of the net, and work forward to the trawler, but in practice the performance of the gear depends upon the

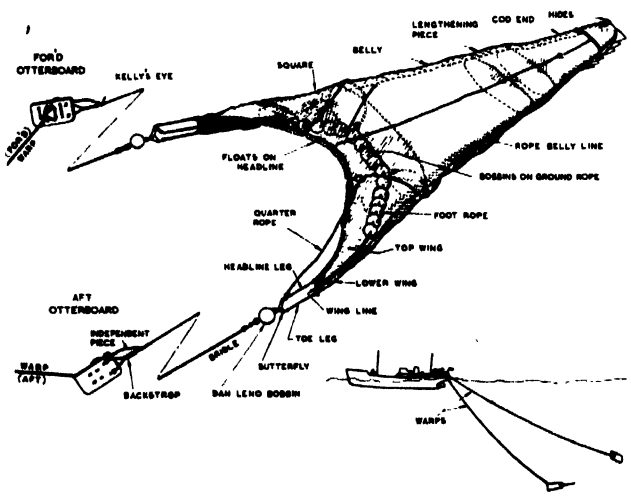

Fig. 1. Typical bottom trawl layout reproduced by permission of the Gourock Rope Co., Ltd.

amount of warp out, the speed of tow, the depth of water and the type of sea bottom, so that in analysing performance it is convenient to start at the ship and work aft.

The instruments used for obtaining the data reported on in this paper are described in Nicholl's paper in Section XIV in which also appears Dickson's paper "Performance of the Granton Trawl".

2·1 The behaviour of warps

The warps take up shapes under tow that are in general curved both in planform and elevation as shown in Fig. 2. These curves depend upon warplength, water

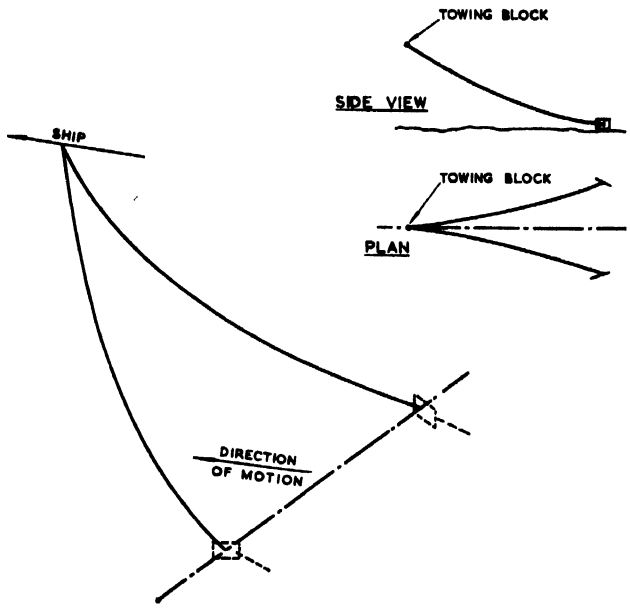

Fig. 2. Warp curvature.

depth, warp diameter, warp weight in water per fathom of length, towing speed, tension in the warp, and lateral distance or spread between the lower ends of the warps. The warp shape varies with towing speed because of the hydrodynamic water force that is generated by moving the warp through the water, and the magnitude of this water force depends upon the extent to which the warp vibrates.

Special electronic acoustic instruments shown in Fig. 3 have been employed for measuring the spread between the lower ends of the warps directly. The bodies are towed by wires which are attached to the warps, about 25 fm ahead of the otter boards. The conical tails, which stabilise the bodies directionally, are based on Kelvin Hughes direct reading current meter practice. However it is undesirable to need to attach this type of equipment to the trawl for every instrumented haul, and in any case other measurements are necessary to determine the effect of warp vibration. It has, therefore, been found best to employ an instrument which measures the "divergence" angle between the warps, just aft of the block, and the "declination" angle of the warps to the horizontal, as shown in Fig. 4. The instrument is simple to install, once the warps are in the block, and systematic readings with it have been obtained for nearly all the test hauls made as part of the investigation.

A set of approximate equations has been developed from which warp curvature can be estimated with

Fig. 3. Electronic Instrument for measuring spread near the otter boards. (a) (on left) Mark II Spreadmeters, the instrument on the right is ready for attaching to the trawl. (b) (centre) Mark II recorder shown withdrawn from the pressure base. (c) (on right) Mark II Electronic Unit

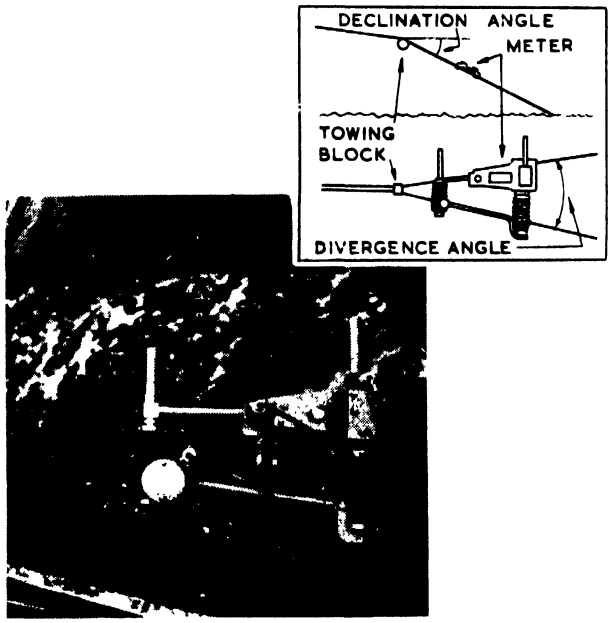

Fig. 4. Divergence and Declination Meter on warps immediately aft of towing block.

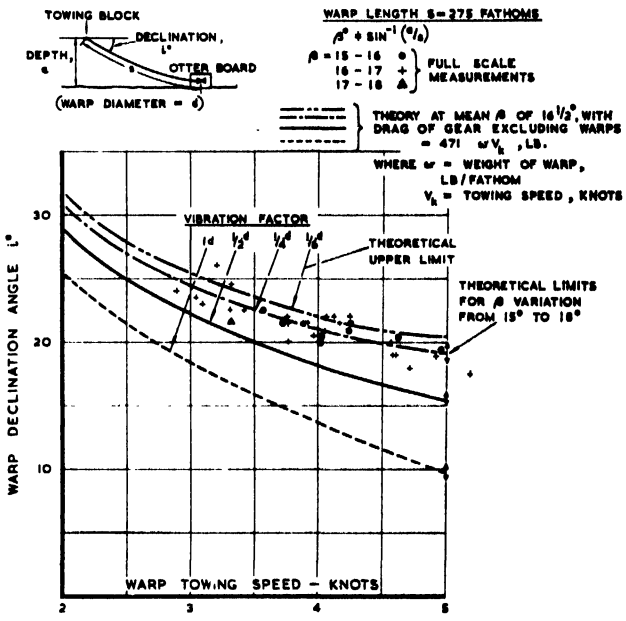

Fig. 5. Variation of warp declination with speed.

sufficient accuracy. Four of these equations, taken alone, provide an adequate account of curvature in a vertical plane. Theoretical estimates for the declination angle, appropriate to different amplitudes of warp vibration, are compared with experimental values given by the instrument, and the effective amplitude of the vibration is deduced, as illustrated in Fig. 5. In the case shown, the "vibration factor" of $\frac{1}{8}$d is appropriate to a non-vibrating condition, and thus gives an upper limit for achievable values of warp declination angle. The vibration is generally of such a magnitude as to increase the hydrodynamic forces by about 50 per cent compared with a non-vibrating wire of the same dimensions (e.g., a vibration factor of $\frac{1}{4}$d as compared with $\frac{1}{8}$d), but a rather greater effect can occur in deep water or in conditions that encourage vibration. The vibration is believed to be due mainly to the wire causing large eddies which are shed alternately from either side, as illustrated in Fig. 6. However, ship vibration and disturbances

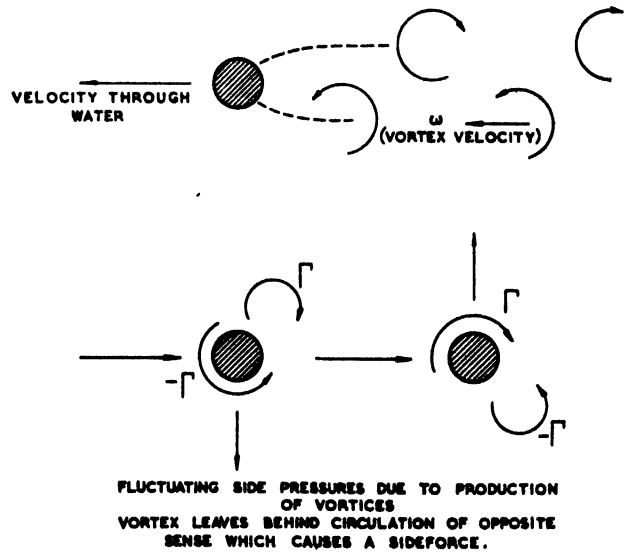

Fig. 6. Vortex street behind a wire rope.

caused by the otter boards may also have some significance.

The estimates of warp behaviour require a knowledge of the tension in the warps. The tension just aft of the block can be calculated from a knowledge of the trawler propeller characteristics and hull form. This has been confirmed by attaching load cells to the warps a little ahead of the block, as shown in Fig. 7. Fig. 8 shows

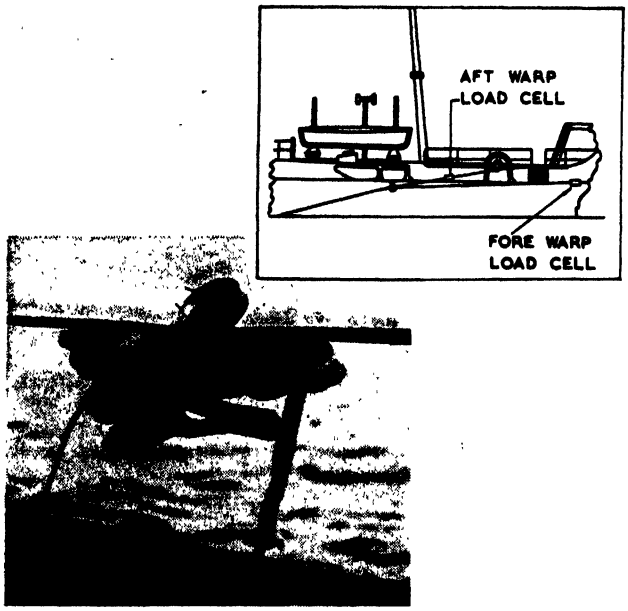

Fig. 7. Load cells on warps ahead of the block.

variation, with ship speed, of towing pull available, and compares points deduced from load cell measurements on a gear of Granton type with curves estimated from propeller thrust and ship resistance calculations. The agreement, which is good, is further supported by direct

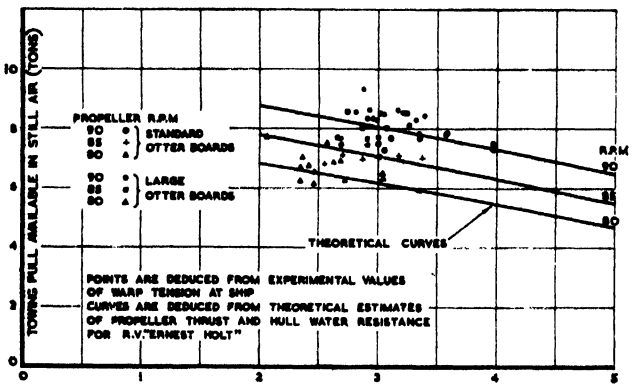

Fig. 8. Comparison of predicted towing pulls with measurements of warp tension. The figures across the graph indicate the ship's speed in knots.

measurements of propeller thrust, obtained from a Michell thrust meter mounted on the propeller shaft (see Fig. 9). All results are converted to still air conditions since the atmospheric wind exerts an appreciable force on the ship superstructure, which may help or hinder its motion through the water.

It may be seen from Figs. 8 or 9 that when measurements of ship speed and engine r.p.m. are available, a value of towing pull can readily be deduced. If, for a given trawl gear r.p.m. is reduced, ship speed and towing pull required tend to decrease almost along a straight line, which cuts the towing pull axis at a small positive value, as shown in Fig. 10. This is because headline

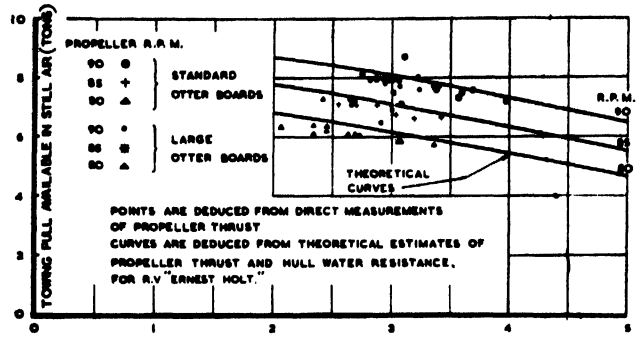

Fig. 9. Comparison of predicted towing pulls with measurements of propeller thrust. Figures across the graph show ship's speed in knots.

height generally increases as speed reduces, for otherwise towing pull required would vary more nearly as the square of speed. (Further consideration of this point is given near the end of the paper.) It follows that if checks of towing pull required are satisfactorily established by direct measurement, at one speed and r.p.m., the speeds appropriate to other r.p.m.'s can be estimated from a knowledge of the ship's propeller characteristics. The tension in one warp is, of course, nearly enough given by (total towing pull)/2 (cosine of warp declination angle), which is approximately equal to (towing pull)/1·85, in most practical cases.

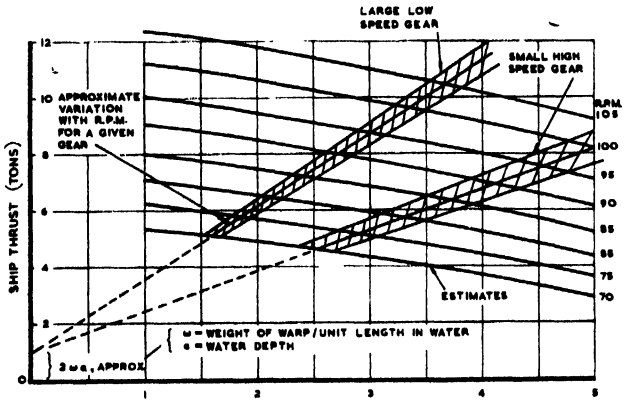

Fig. 10. Towing pull requirements. Figures across show ship's speed in knots.

The tension does not reduce to zero as speed is reduced to zero since it has to continue holding the warps taut, which can theoretically be shown to require a value equal to (depth of water) × (weight of warp in water per unit length); e.g., a 3·25 in circumference warp weighing 8·5 lb per fm, requires a tension of 850 lb in 100 fm of water. When the gear is under way, the tension at the bottom of the warp is less than that at the top by

the above quantity together with the component of force parallel to the warp that is produced by the water flowing past it. This has been confirmed by measuring tension both ahead of the block and just ahead of the otter boards. The load cell designed and built for the latter purpose is shown in Fig. 11, and the differences

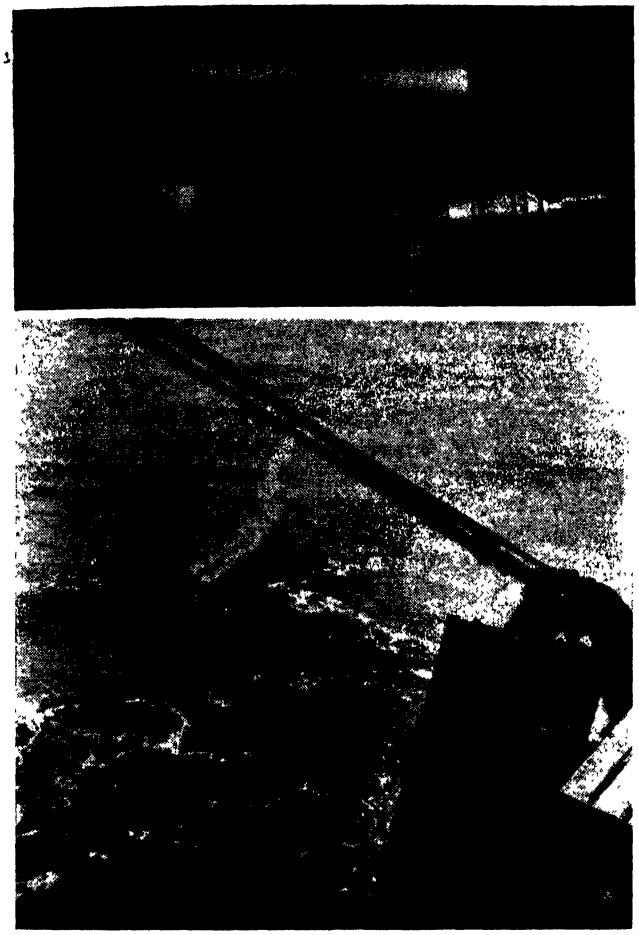

Fig. 11. Load cells for measuring forces in wires. (Top) Load cell dismantled. (Bottom) Load cells in place as seen from gallows before shooting.

in experimental tension between the top and bottom of the warp are compared with theoretical estimates in Fig. 12. The component of water force parallel to the warp is given nearly enough by:

$$\tfrac{1}{2}\,\rho\,(\pi\,d\,s)\,(1{\cdot}689\,V_k)^2\,C_T,$$

where ρ is water density in slugs per cubic foot, d and s are warp diameter and length in feet, and V_k is speed in knots. The coefficient C_T is due partly to skin friction, and also to water pressure on the strands of the cable.

Let us now return to the general performance characteristics of the warp. Once the tension (or towing pull) and the effective magnitude of vibration have been established, as illustrated in Figs. 8 and 5 respectively, curves of warp length required to give any desired angle of the warp to the vertical, at its attachment to the otter board, can be calculated. A digital electronic computer was employed for this purpose, a sample set of results being shown in Fig. 13. These refer to fishing with 275 fm of warp aft, in various depths of water, and at various ship speeds. The weight of warp in water in lb per fm, w, can be given any suitable value when using this dia-

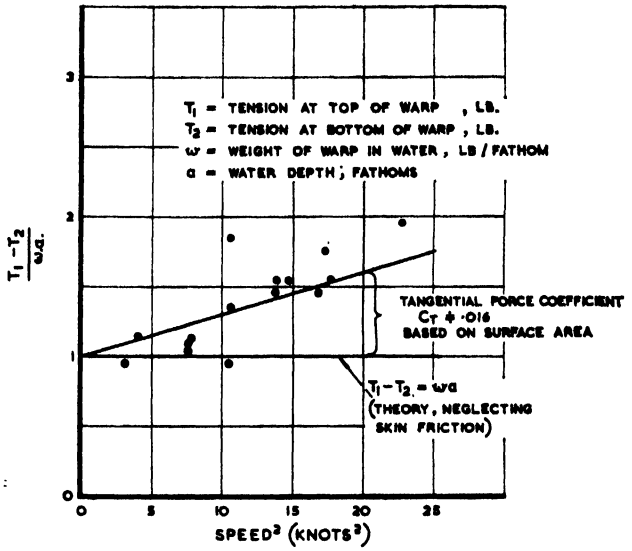

Fig. 12. Warp tension differences.

gram. It should however be noted that the results only apply if the drag of the gear is proportional to w. To obtain specific results, for a case with a drag that is characteristic of distant-water trawls, a value for w for

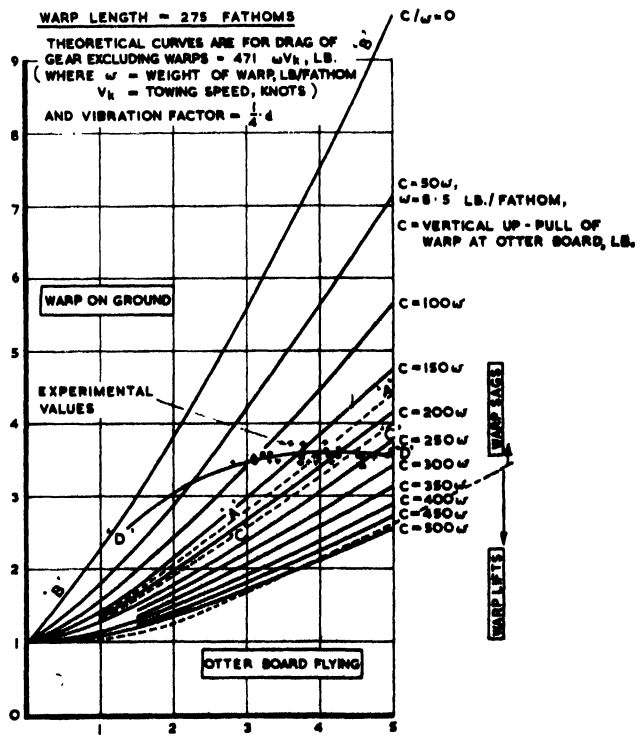

Fig. 13. Typical warp length/water depth curves. The vertical scale gives the ratio of warp length to water depth and the figures across, the towing speed in knots.

8·5, appropriate to a 3·25 in circumference warp, may be considered.

Each line corresponds to a different constant value of vertical upward pull of the warp on the otter board bracket, the appropriate values being given adjacent to the lines. Experimental fishing conditions for a 3·25 in warp are shown by points. In these cases the warplength to water depth ratio used was about 3·5 irrespective of speed. Some variation with speed should give a rather better performance, as will now be discussed. To keep a given up-pull on the board, the warplength to depth ratio should be varied with speed along one of the constant up-pull lines, as for example by the variation marked A-A. If so much warp is paid out that values of length to water depth lying above line B-B occur, then there is no up-pull, the lower end of the warp lies on the seabed and the otter board comes down on its bracket. For a normal otter board weight in water of about 0·75 ton, the board will be pulled off the bottom when the vertical up-pull significantly exceeds 0·75 ton. This occurs for warplength to depth ratios lying below the line C-C, say. If otter board behaviour depended only on water forces arising from its motion through the water, the up-pull would be required to vary as speed squared to keep the board upright as speed varied. This would demand an almost constant warplength to depth ratio, irrespective of speed, as shown by the line D-D. Due to the presence of weight and buoyancy forces, that do not vary with speed, the variation required in practice will be between that of line D-D and the values indicated by an appropriate line of constant up-pull.

It is of interest to compare the theoretical estimates of required variation of warplength to depth, with trawler skippers' "rule of thumb" practice. This is done in Fig. 14 for varying depths and characteristic trawling

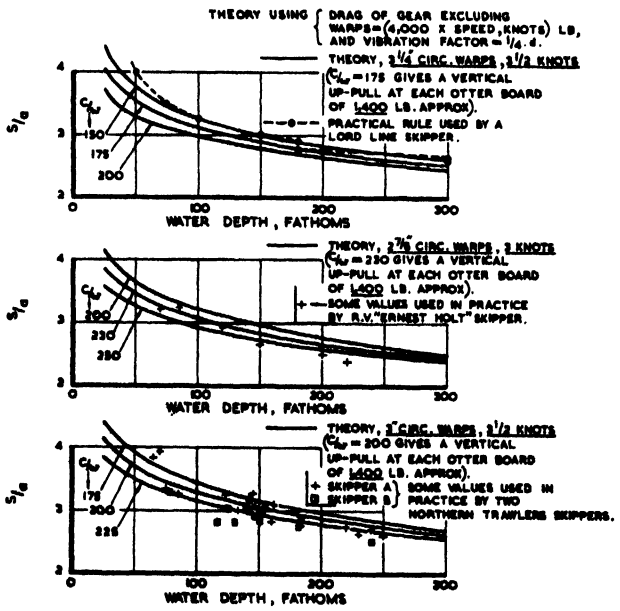

Fig. 14. Comparison between theoretical variations of ratio of warp length to water depth against water depth with values used by practical fishermen.

speeds. It will be seen that the agreement is good, as would be expected from the very extensive practical experience upon which such rules of thumb are based. A characteristic value for the weight in water of a distant-water otter board is 1,700 lb so that the lengths of warp used in practice leave about 300 lb of the board weight to press on the seabed. This reserve permits a reasonable variation of speed and water depth to occur, at a given length of warp aft, without the board being pulled off the seabed.

The behaviour of the warp in vertical projection has been satisfactorily explained, assuming that, both with and without vibration, and apart from buoyancy, the resultant water force nearly enough lies in a plane containing the direction of motion and the straight line joining the ends of the warp, and is perpendicular to the latter straight line, i.e., it is as N_1 in Fig. 15a.

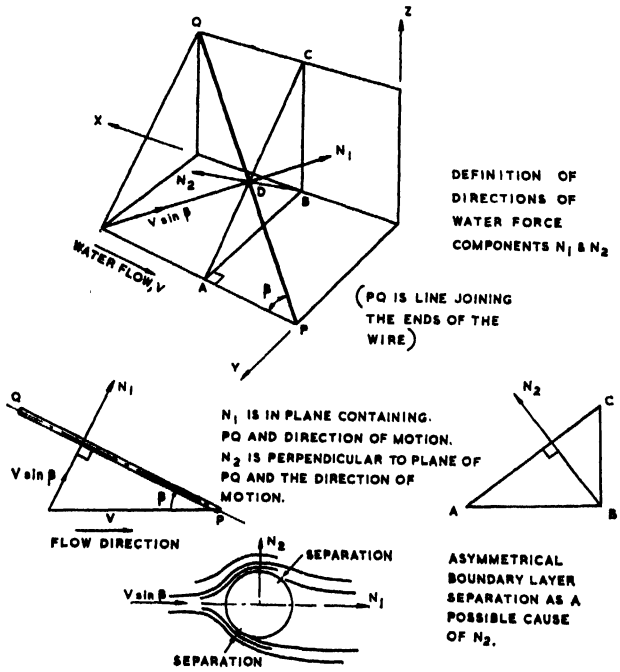

Fig. 15a. Components of water force acting perpendicular to a wire.

Returning to curvature in plan, it would appear, from the experimental data so far available, that a "normal" water force, N_2 say, also defined as in Fig. 15a, may act in addition. For example Fig. 15b gives ratios of theoretical spread at the otter boards, assuming N_2 to be zero, to the value which would be obtained from the divergence meter if the warps were assumed to be straight in plan-form. In the cases given values of about 1·15 are appropriate to representative towing speeds. The corresponding electronic spreadmeter readings agree rather well with the estimates, as shown by the test points obtained with that instrument. In other cases not shown here, experimental factors as high as 1·4 have been obtained. Investigation of this matter continues and if it is found that N_2 zero theoretical values do not lie sufficiently close to experiment the theory will be elaborated accordingly. N_2 would be non-zero if the "boundary layer"

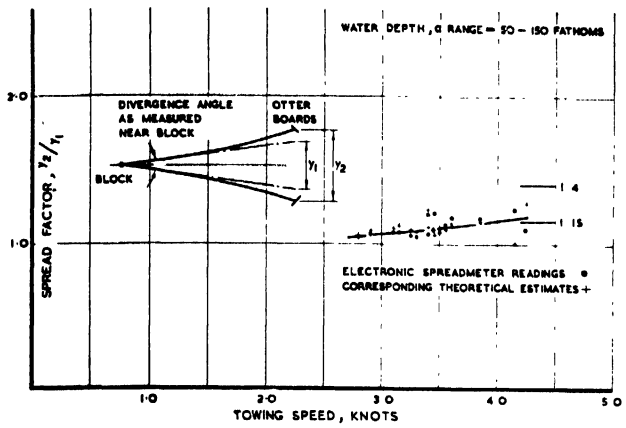

Fig. 15b. Warp planform spread factors.

of the flow past the warp separated from the surface of the wire at different longitudinal stations on the top and bottom surfaces respectively, as illustrated in Fig. 15a. This might occur due to the variation in hydrostatic pressure from the top to bottom of a transverse cross-section of the wire, which arises from the density of water, since this pressure change is of the same order as the hydrodynamic pressures caused by the motion of the wire through the water. Again the recently published reference 7, of 15th February, 1963, describes how stranded electrical cables, in air, can have this type of asymmetrical separation, due to the lay of the strands presenting different profiles to the fluid, at opposite ends of a diameter of the cable.

In addition to the above possibilities, the lay of a stranded cable whose axis is inclined to the direction of motion is known to generate a hydrodynamic force, in the N_2 direction, by causing fluid to swirl round the wire (see Fig. 16). The magnitude of this component

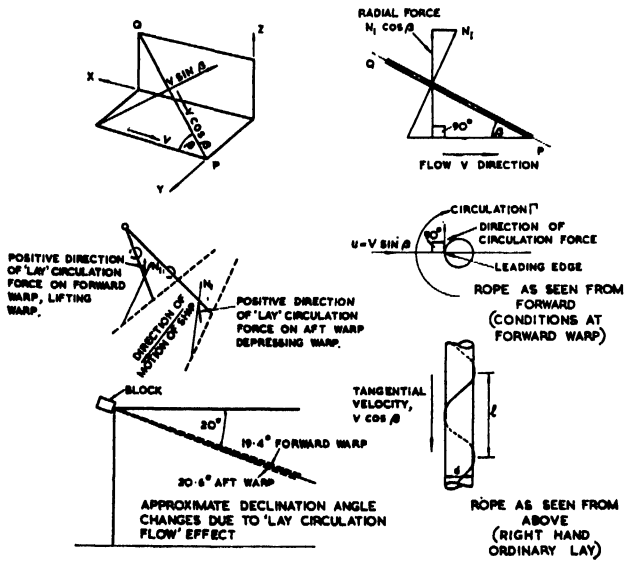

Fig. 16. Circulation forces due to warp lay.

of N_2 is not likely to be very large, however, and would be expected to make the planform curvatures of the two warps different from one another, without appreciably affecting the spread at the lower end relative to the divergence angle. Asymmetry in the planform shape of the two warps, arising from the swirl component of N_2 would be eliminated by using handed warps. Asymmetrical boundary layer separation might be prevented by encasing the warps in a smooth plastic sheathing. It would be of academic interest to make experiments under these conditions. The relatively small spread factor of about 1·15, that has been measured with traditional laid warps (see Fig. 15b), is an advantage in practice since only a small correction has to be made to the readings obtained directly from the divergence meter, in order to obtain the spread of the otter boards.

When a gear is turning, the spread at the lower end can greatly exceed 1·4 times the value given by the angle between the warps at the block. This has been confirmed by the electronic spreadmeter, and an extreme example is provided by the technique of turning the ship at such a high speed that the warps cross, and yet the boards remain well spread.

2·2 Otter board forces and moments

The mathematical evaluation of otter board performance is a complicated matter. In essence they behave like small aspect ratio aerofoils but they operate at considerably greater attitudes and over a considerably greater range of angles of heel than is usual for the latter (see Figs. 17 and 18). Also the otter board may have appreciable tilt so that it runs on its heel rather than with the sole plate equally in contact with the seabed all along its length (Fig. 19).

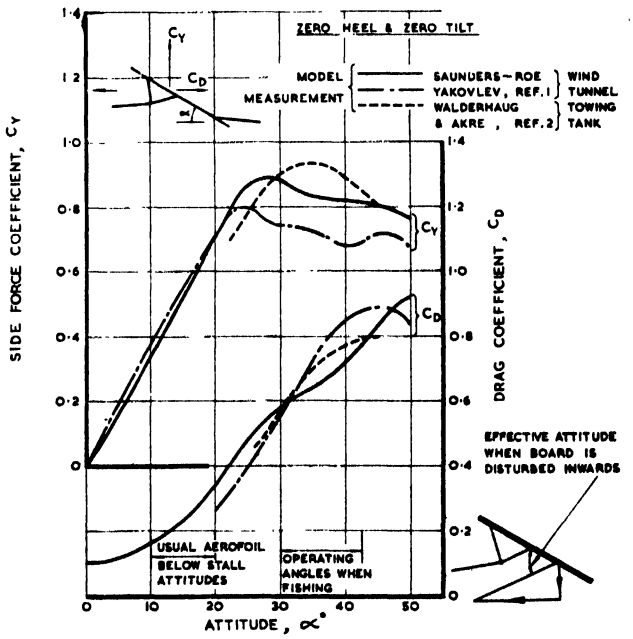

Fig. 17. Typical hydrodynamic side force and drag coefficients for flat rectangular otter boards of aspect ratio ≒ 1/2.

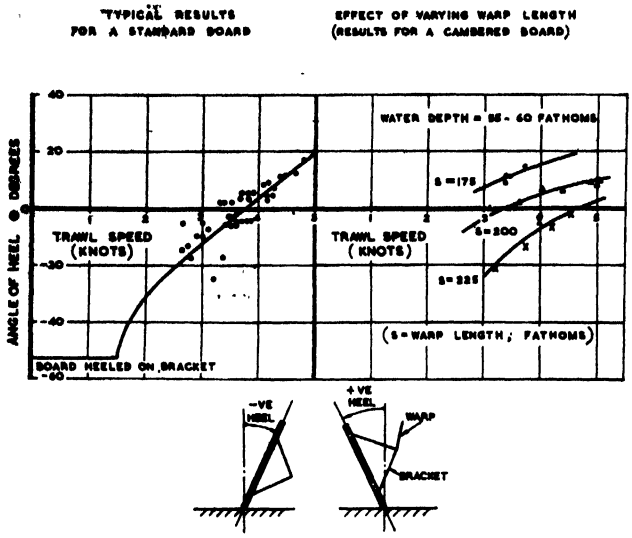

Fig. 18. Variations of otter board heel with speed. Full-scale tests.

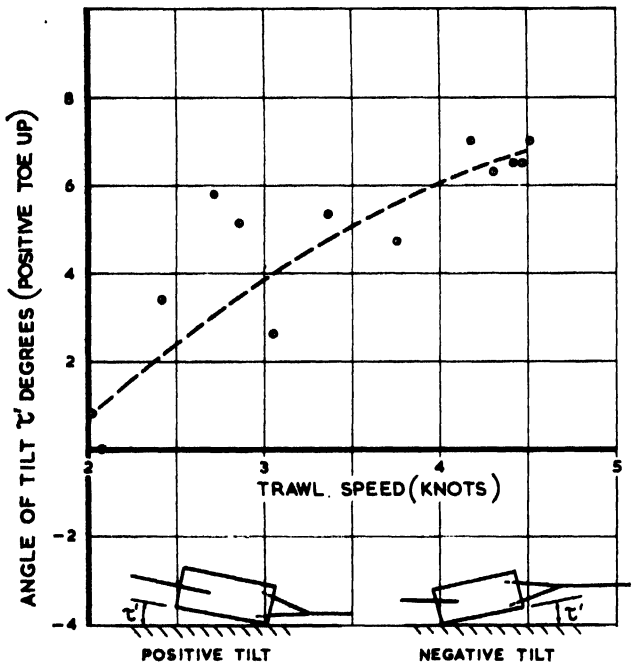

Fig. 19. Some measured variations of tilt with speed, standard otter board. Full-scale tests.

The large change in heel with towing speed, at a given warplength and depth of water, is perhaps the most immediately striking characteristic of the results shown in Figs. 17 to 19. From the left-hand side of Fig. 18 it will be observed that, when using a traditional warplength aft, a "standard" flat distant water otter board was almost upright at the towing speed of about 3·5 knots, at which it was customarily used. From the right-hand side of Fig. 18, a change of towing speed of one knot requires a change in warplength of about 15 per cent in order to preserve a given angle of heel. This is, of course, consistent with rule of thumb trawling practice. Fig. 18 gives results determined by full-scale experiment but the change in warplength necessary to maintain a given heel can also be deduced from theoretical curves such as those of Fig. 13.

Referring to Fig. 17, the proximity of the seabed alters the effective aspect ratio, defined as (height)^2/surface area, as is the case also with an aerofoil, but, in addition, so-called "ground shear" forces arise due to seabed material piling up against the lower face of the board and sliding along it, or due to the board catching on the bottom and proceeding in a jerky fashion.

The "aerofoil type" forces can be determined from measurements of a model in a wind tunnel, a "ground" being placed adjacent to the otter board to represent the seabed (see Fig. 20). The quantities measured are sideforce, drag, lift, "pitching moment" and "yawing moment", defined as in this figure.

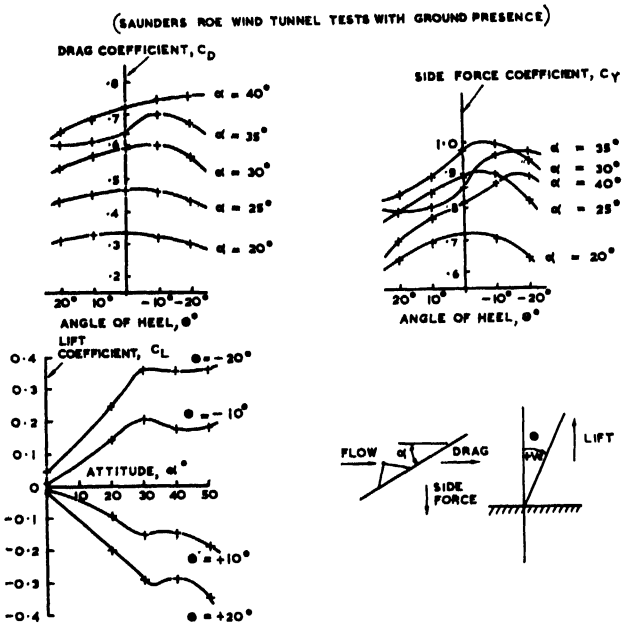

Fig. 21. The effect of heel on the hydrodynamic forces acting on a flat rectangular otter board of aspect ratio≒1/2.

Typical model test results for an unheeled otter board are shown in Fig. 17, while Figs. 21 and 22 refer to the effects of heel and tilt.

When presenting these figures, the customary fluid dynamic coefficients have been used, instead of giving forces in lb or kg. Thus for example sideforce coefficient

$$C_Y = \frac{\text{sideforce, Y lb,}}{\frac{1}{2}\rho\, S_B\, (1{\cdot}689\, V_k)^2}$$

where ρ is the density of water in slugs per cubic foot ($\frac{1}{2}\rho$ is nearly enough 1·0 for salt water), S_B is the area of one side of the board, projected on a plane through its leading and trailing edges, and V_k is towing speed in knots. Similar definitions give the drag coefficient C_D and the coefficient of upward vertical force, C_L, which is near enough zero at zero heel (see Fig. 21). By employing this type of presentation, and making the usual assumption that the coefficients are near enough independent of speed and of the size (but not the proportions) of the board, the forces appropriate

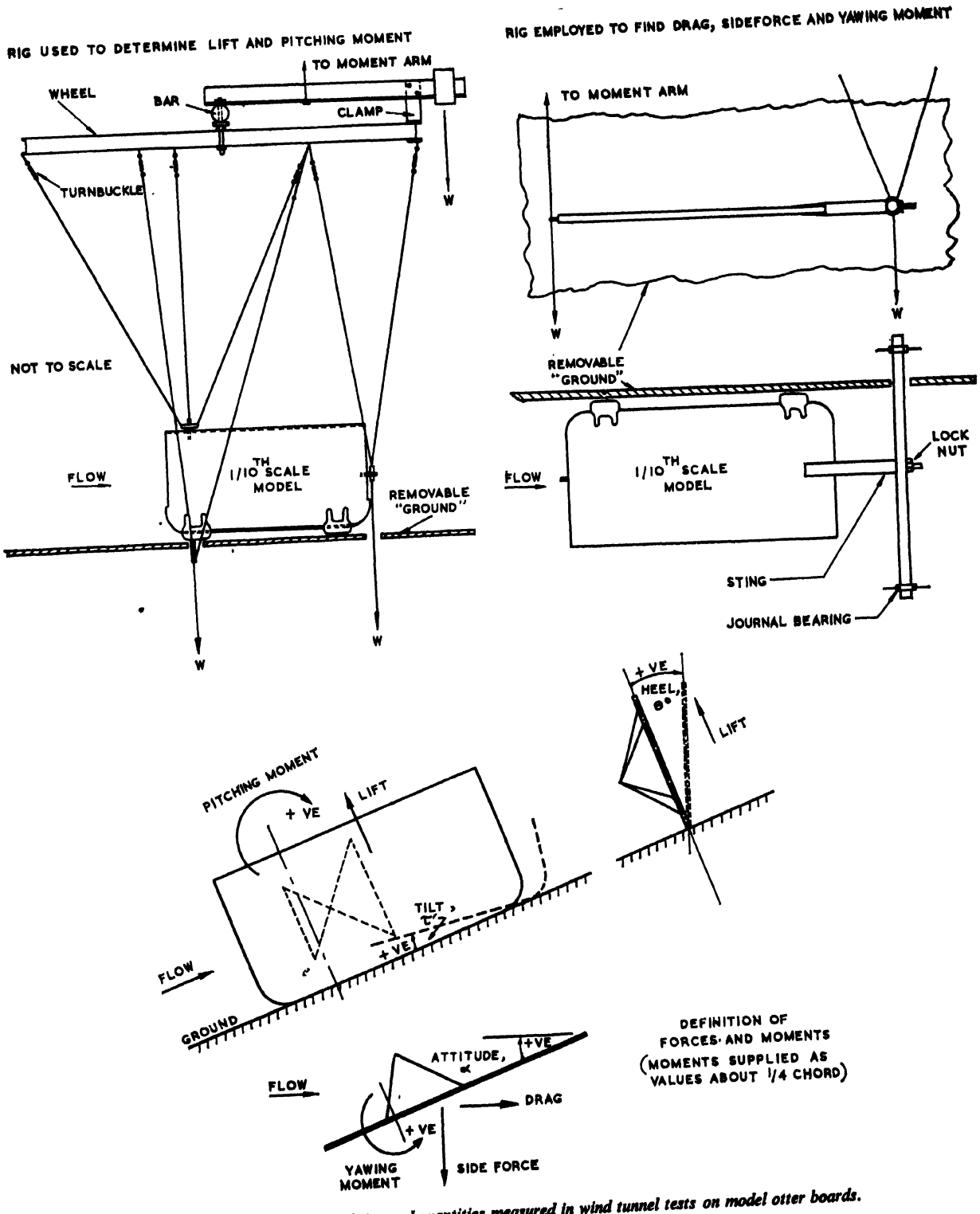

Fig. 20. Diagrams of rigs and quantities measured in wind tunnel tests on model otter boards.

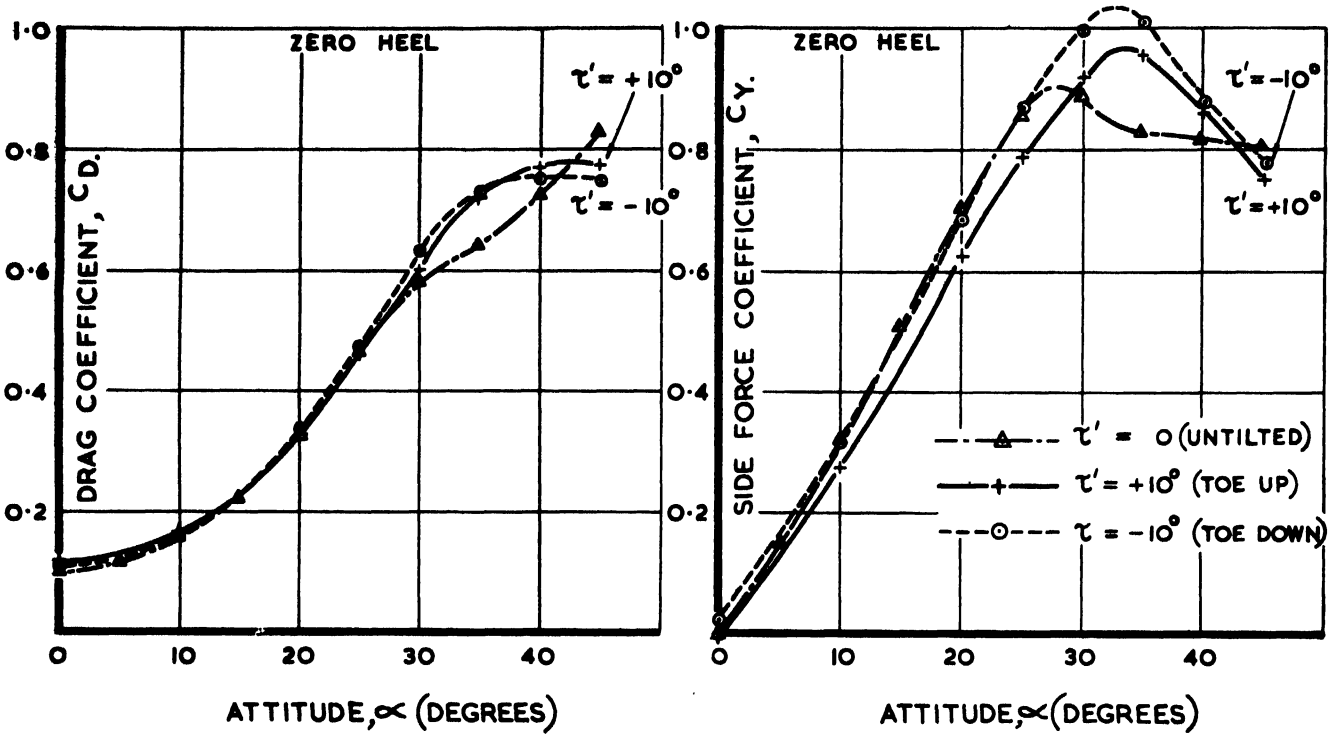

Fig. 22. The effect of tilt on the hydrodynamic forces acting on a flat rectangular otter board of aspect ratio ≒ 1/2.

to any chosen speed and size can rapidly be deduced. In practice the drag coefficient C_D shows more tendency to vary with size and speed than do C_Y and C_L, but to first order, constancy can still be assumed.

From Fig. 21 it will be seen that maximum sideforce occurs when the board is heeled inwards (i.e., -ve heel with bracket towards the seabed). A heel of about —10° is appropriate to a practical attitude in the 30° to 40° range. This maximum sideforce is associated with a rather larger drag than occurs at the positive angle of heel of the same absolute magnitude but for overall force efficiency the warp should be long enough to allow the board to be heeled a little inwards. This does not necessarily increase the pressure of the board on the seabed. The water force acts nearly perpendicular to the board surface so that while lengthening the warp reduces the warp up-pull, heeling-in gives a compensating increase in vertical hydrodynamic force.

From Fig. 22, a small amount of tilt does not greatly affect the force efficiency but the sole plate should be kept at 5°, or less, to the horizontal. As might be expected from theoretical considerations concerning the effective aspect ratio of an aerofoil adjacent to a ground, nose-up tilt reduces sideforce more than nose-down tilt. The latter can lead to digging in however.

The centre of pressure at which the resultant hydrodynamic force acts can be determined from the measured quantities, including yawing moment, and is as illustrated in Fig. 23.

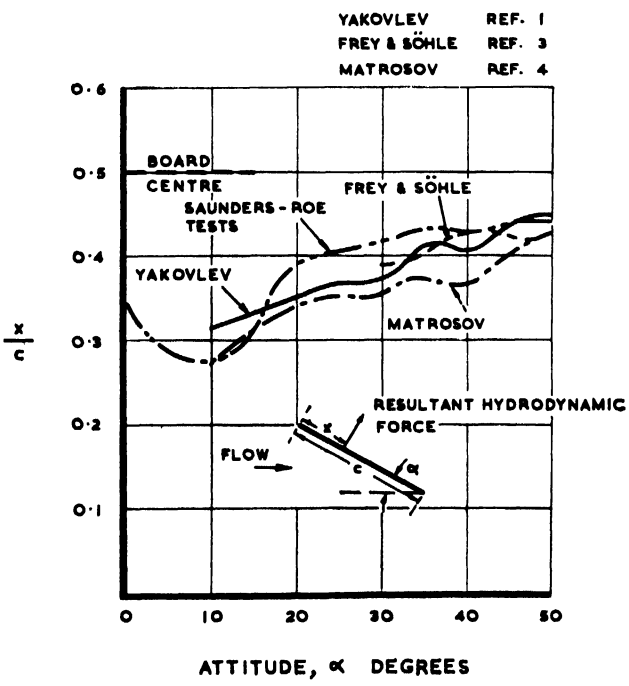

Fig. 23. Variation of centre of pressure with attitude: rectangular flat otter boards of aspect ratio ≒1/2 with ground effect (from model otter board tests at zero heel).

Influence of camber

So far the performance characteristics of flat otter boards have mainly been discussed. The considerable increase in sideforce that can be obtained by giving a board curvature (i.e., camber) in longitudinal section is shown by Fig. 24. It will be seen that if a moderate camber is

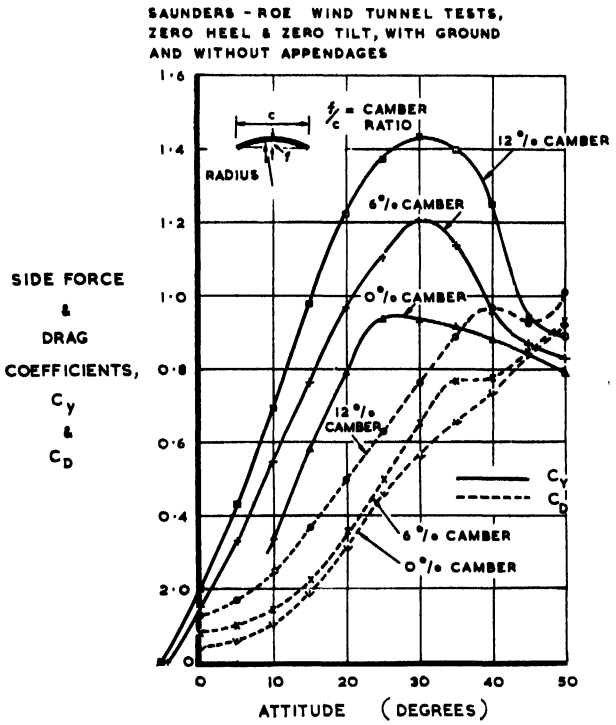

Fig. 24. The effect of simple camber on the hydrodynamic side force and drag of aspect ratio÷1/2 otter boards.

used, the drag penalty is small and the sideforce to drag ratio is thus appreciably improved. These wind tunnel results have been supported by full-scale measurements. By contrast, neither our tests of oval boards nor other tests which have been published show such a large advantage. Furthermore, an oval board occupies a space behind the gallows which can accommodate a rectangular board of about 25 per cent more area, and this alone appears to be enough to counterbalance the rather greater sideforce coefficient provided by the oval board as compared with a flat board. Referring again to Fig. 24, it will, however, be seen that in order to achieve maximum values of sideforce coefficient it is necessary to tow the board at an attitude of about 30°, as compared with the 40° or more that is usual with flat boards. The implications of this will be discussed in connection with the stability of otter boards.

Figs. 17, 21, 22, 23 and 24 have been concerned with hydrodynamic forces arising from flow of water past the boards. Further attention to "ground shear" forces will now be given. It is impossible to determine whether a model simulation of the latter is reliable without first measuring them full scale. Therefore, this has been done, employing the specially instrumented otter boards shown in Fig. 25. Five load cells, of the

Fig. 25. Instrumented otter board with covers removed to show load cells for measuring ground forces in three directions and cut-outs for tilt, heel and attitude recorders.

type used in the warps at the otter boards but of smaller dimensions and capacity, are employed to measure the ground forces that act on the sole plate in directions parallel to the plate, and sideways and upwards perpendicular to the plate (see Fig. 26). Some results are shown

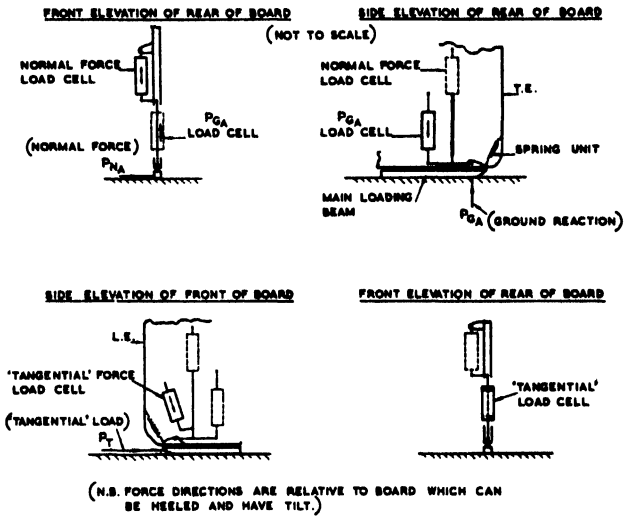

Fig. 26. Full-scale otter board ground force measurement instruments (location and action).

in Fig. 27. It will be seen that the vertical component can be about 30 per cent of the otter board weight in water, while the "sideways" component can be about 50 per cent of the weight, and as such can provide a considerable part of the overall spreading action of the board. As might be expected, the ground shear appears to be more significant on muddy bottoms than on hard bottoms. However if the board is made rather heavy in water, so as to get a purchase on the mud, it can sink in to about one-quarter of its overall height, thus tending to offset the gain in ground shear by a loss in hydrodynamic spreading force. It is tentatively concluded that when designing boards to achieve ground shear spreading effects, careful attention must be paid to the type of grounds on which it is intended to use them.

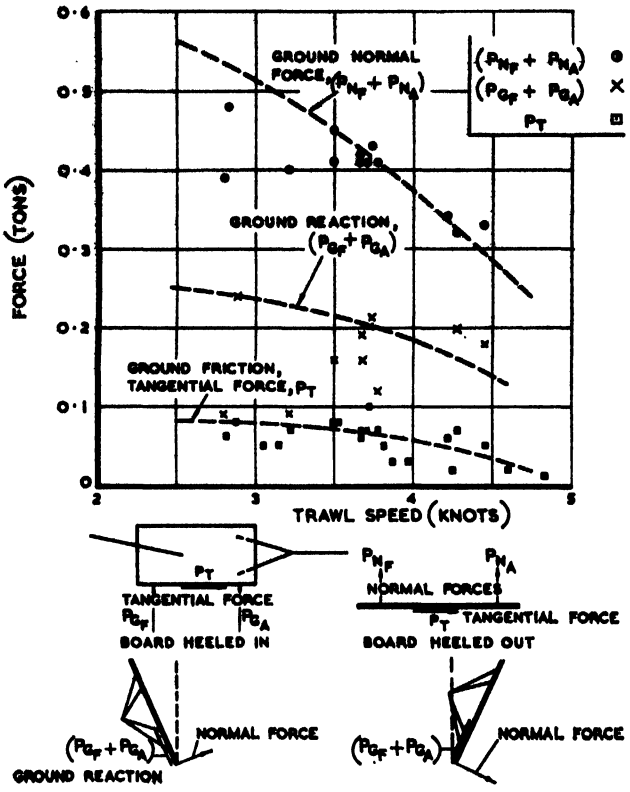

Fig. 27. Full-scale otter board ground force measurements.

2·3 Otter board stability

To design an otter board properly requires consideration, not only of the spreading force and drag that will act on it, but also of its stability. Static stability is concerned with its ability to tow steadily at constant values of spread and constant angles of attitude, heel and tilt. Dynamic stability is concerned in particular with three conditions of unsteady motion.

(a) When a board is shot, it must take up a series of positions, as warp is paid out, that will bring it to a reasonable spread and nearly unheeled condition on the seabed. When the warps are blocked up they will then be level.

(b) When a warp is shortened, the board should pull off the seabed without heeling or tilting excessively, so that it will continue to provide spread and can go down on the seabed again without falling over on its back.

(c) If the board is disturbed during steady towing, as for example by being deflected or heeled over due to an obstacle being encountered, it must automatically return to its condition of steady motion.

The six equations of force and moment equilibrium of an otter board have been formulated, from which the bracket and backstrop locations necessary to provide a desired attitude and angle of heel, at arbitrarily chosen steady towing speeds, spreads and sweep tensions and directions, can be determined. The calculated positions are confirmed by tests on small models in our towing tank. The same equations have been used to calculate behaviour when pulling a board off the seabed, and in shooting. The latter can demand wire attachment positions that differ from those that would give maximum force efficiency in towing. Some compromise is then necessary. Model tests of shooting behaviour have been made and help to clarify full-scale observations. It must be emphasised that the increased force efficiency of a cambered board arises from its forward surface being at a smaller angle to the direction of motion than in the case of a flat board, thus allowing the water to flow round it more smoothly. The effect is reinforced by the smaller attitude, 30° as compared with 40°, at which the cambered board behaves best when towing. This reduction in required towing angle, which, at least to some extent, will be a feature of any board having high force efficiency, tends to give too small an angle when shooting or hauling. This can however be overcome by keeping more way on the board. Prototype devices have also been used with some success for reducing the attitude of the board, relative to the warp and backstrop, as soon as it contacts the seabed.

Stability in steady tow can be studied in terms of force data such as those of Fig. 17. It will be observed for example that if a standard otter board, fishing at an attitude of about 40° is disturbed so as to decrease spread, then due to its inward motion, effective attitude is increased, spreading force reduces and the tendency to decrease spread is encouraged. Such a disturbance applied to a board which is fishing at attitudes below the stall should, on the contrary, rapidly be damped out, due to the positive slope of sideforce against attitude in that region.

The warp and otter board force and moment equations that have been elaborated are equally useful for designing bottom gear and midwater trawl gear. The most suitable aspect ratios (height^2/area) for the different applications are being investigated.

2·4 Width of mouth of net

Next attention should be turned to the relationships between bridle tension and angle, board spread, spread of the net mouth, and drag of the gear. Here, the term "bridle" will be taken to mean the total wire system between the wing end of the net, and the otter board, including legs, cables or sweep wires, and otter board backstrops.

The headline and ground rope of the net take up planform shapes that are near enough catenaries with linear extensions forward. This is reasonable bearing in mind that the aft pull on these wires, due to the drag of the net and its appendages, such as floats and ground rope bobbins, will to a first approximation, be constant per unit length of wire except in so far as it is concentrated due to local grouping of the appendages. Confirmatory experimental evidence has been provided by scratch marks on the bobbins, full-scale, and by photographs of tank models, such as illustrated in Fig. 31.

Formulae have therefore been developed on the above basis, which relate:

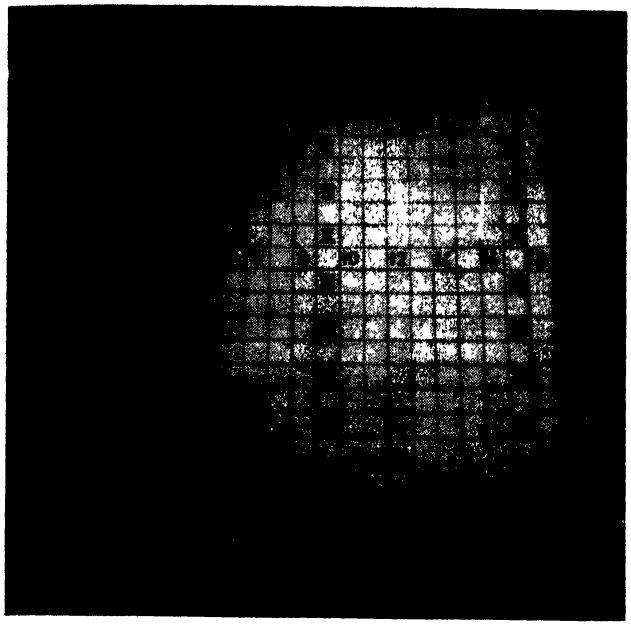

Fig. 31. Model net in towing tank.

ground rope planform angle at wing end, δ_g.
headline planform angle at wing end, δ_h.
width between ends of headline, $2y_h$.
width between ends of ground rope, $2y_g$.
and ratio of ground rope width to headline width, y_g/y_h.

These quantities are defined in Fig. 28. Various headline ground rope and leg lengths, and various proportions of straight to catenary length for the ground rope, defined by a quantity μ, have been assumed, the headline being taken as a pure catenary.

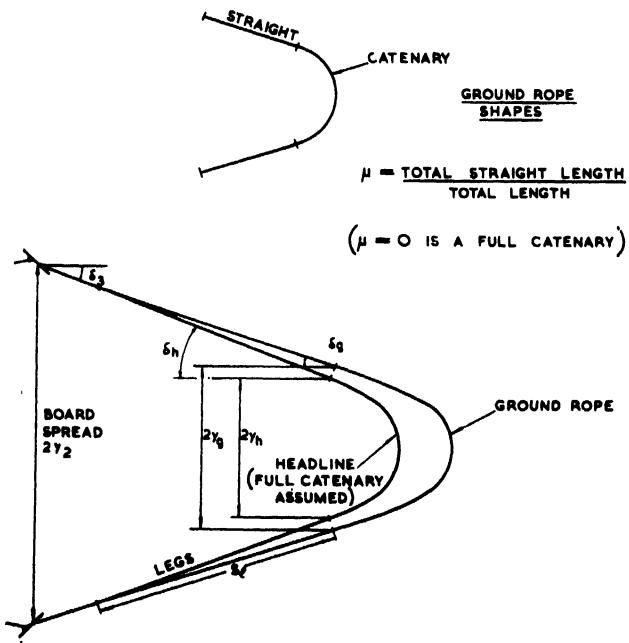

Fig. 28. Definition of plan shape parameters used in Figs. 29-34.

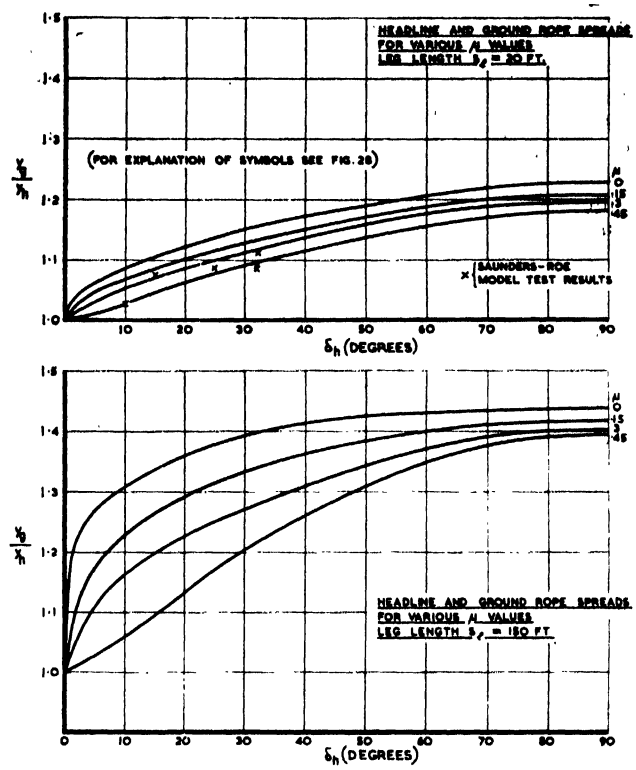

Fig. 29. Headline and ground rope planform calculation results.

Some results are given in Figs. 29 and 30 together with confirmatory test results obtained with small towing tank models, such as that of Fig. 31. The model test results given in the upper part of Fig. 29 refer to a

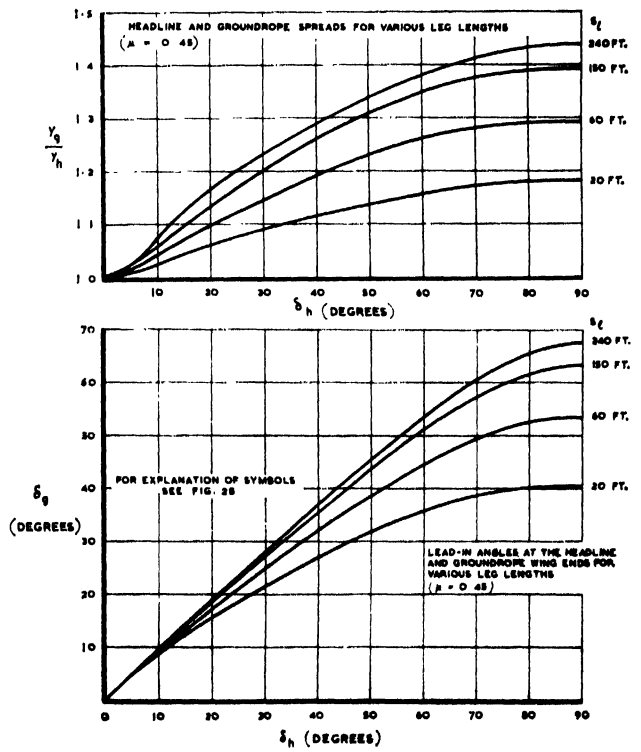

Fig. 30. Headline and ground rope planform calculation results.

Granton type of gear, and indicate that the ground rope ahead of the bobbins is nearly straight. Full-scale scratch marks have shown this also. When a gear is spread wider, μ tends to zero however. The lower part of the figure indicates that when long legs are used the wing end spreads at the headline and ground rope can differ significantly, especially at the higher spread angles. The nature of the dependence of y_g/y_h on leg length is illustrated by Fig. 30.

A development of the theory has been used to calculate the corresponding spread at the forward end of the leg and cable system, and the planform angle of the cable at the backstrop, taking account of the effect of water forces in curving the leg and cable wires in planform. To perform this calculation it is, however, necessary to know the ratio of tensions in the head and toe legs. Load cells mounted in the legs of full-scale gears have given suitable values for this ratio. Some calculated results for spread at the backstrops of the otter boards, in relation to the spread of the groundrope and headline at the wing end, are given in Fig. 32. The effect of

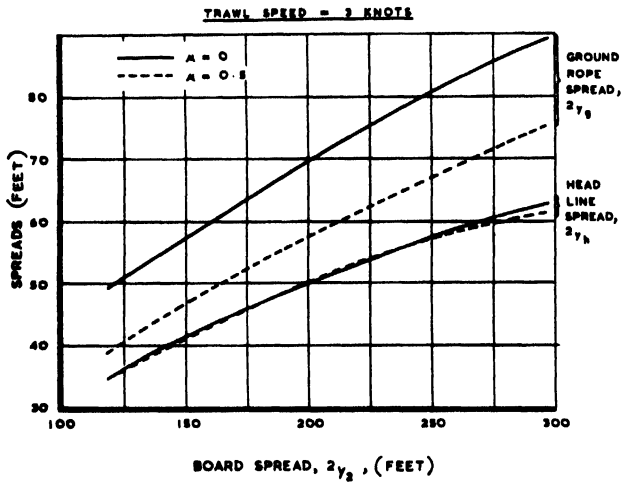

Fig. 32. Calculated headline and ground rope spreads for a particular trawl.

changing μ will be seen. In practice the headline also ceases to be a pure catenary, at large spreading angles, due to constraints applied by the wings, or selvedge ropes. Fig. 33 compares ground ropes spread against wing end angle with towing tank model results. In this case a μ of zero was found to be adequate. Fig. 34 gives estimated otter board backstrop planform angle against otter board spread for a given net and leg length.

It will be seen from Fig. 35 that the otter board spreading force required to provide a given spread of a gear of known drag can now be determined from the warp and bridle theories and otter board data that have been mentioned in this paper. In general allowance must be made for board heel.

2·5 Drag of the net

It remains to relate net drag to its specification and mouth height and spread. Both model and full-scale data have

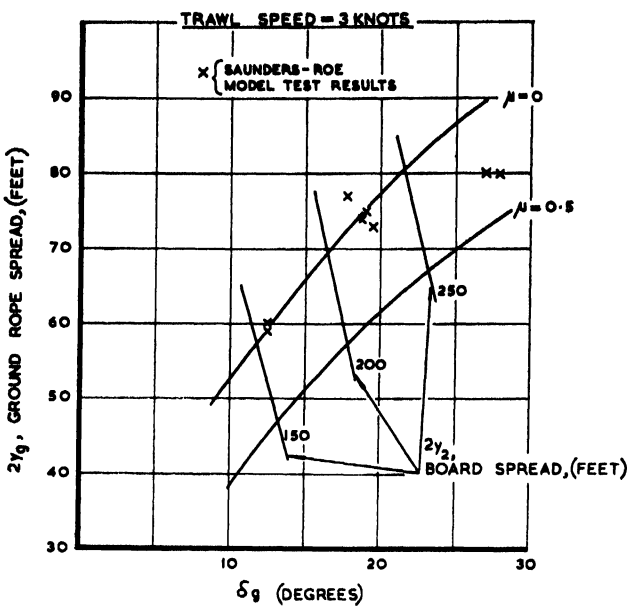

Fig. 33. Calculated ground rope spread with ground rope plan angle for a particular trawl.

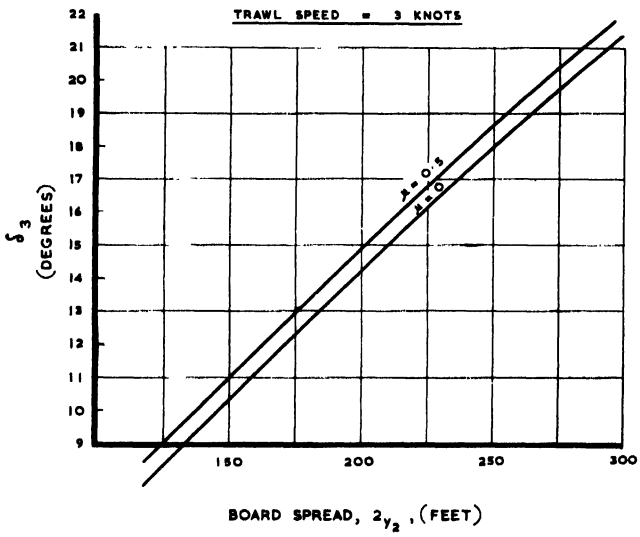

Fig. 34. Calculated otter board backstrop plan angles with board spread for a particular trawl.

been obtained on this, and theoretical estimates have also been made, based upon tank model measurements, of the forces on simple plane specimens of net webbing. Some results are illustrated by Figs. 36 to 39.

Fig. 36 shows the variation of the resistance of a plane net specimen having a constant characteristic setting angle φ of 30°, when θ, the angle of the plane of the webbing to the direction of motion, varies between 0° and 90°. Also shown are curves of theoretical and partly empirical formulae for estimating the resistance.

As in the case of otter board forces, it is convenient to use webbing force coefficients, rather than forces in lb of kg. "Twine coefficients" are based on a "nominal frontal area" of solid material in a mesh, 2ad, where a is

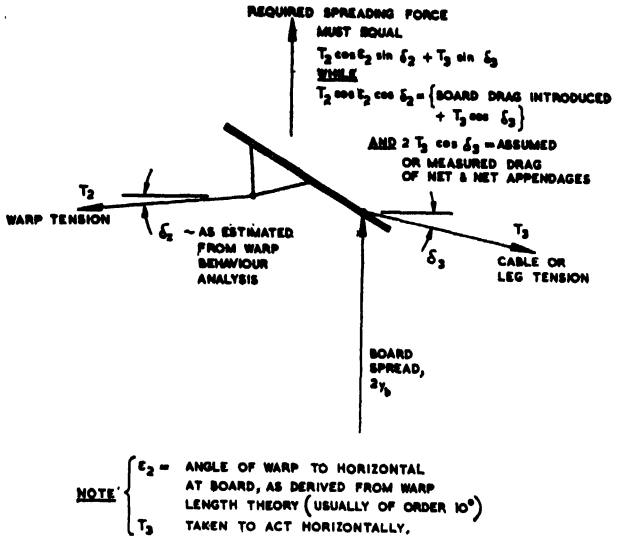

Fig. 35. Simple illustration of otter board spreading force requirements.

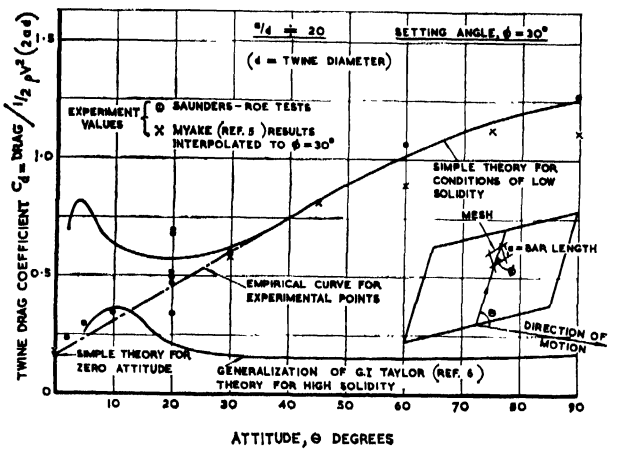

Fig. 36. Resistance of plane net specimens.

bar length between knot centres, and d is the twine diameter. To obtain the drag per square foot of webbing, it is necessary to multiply by d/a sin φ cos φ. If the area of webbing is calculated at a standard setting angle of 45° say, then φ would be taken at this value in the multiplier, but not elsewhere.

It will be seen that at attitudes, θ, above about 30°, a simple theory applies quite well. This assumes that the water speeds up so that the same volume passes through the area of the netting as would pass in the absence of the netting, the bar and knot components of the webbing having the same drag as would occur if they were each tested separately in a stream of such increased speed. At smaller attitudes the effective velocity of the stream is reduced due to water being deflected round the sides of the specimen. Sir Geoffrey Taylor has produced a theory for wire meshes of high solidity (i.e., small ratio of frontal area of holes to total frontal area) at θ=90°. An attempt has been made to generalise this theory to small θ conditions, at which the effective solidity of net webbing should be high. As will be seen, the peak resistance given by the generalised theory lies close to the dashed line empirical curve drawn through the experimental points, but at smaller and larger θ's, it underestimates drag. Finally a simple expression, similar to that appropriate to large θ conditions, can be derived for drag at zero θ, assuming that the speed of flow of water past the webbing is unaffected by the presence of the webbing, and that the knots have a negligible effect. This agrees well with experiment, for setting angles less than about 40°, which should generally bracket the practical range. At large setting angles interference between longitudinally adjacent webbing components is large, and reduced forces are obtained.

It has been concluded that it is best to employ the simple theories at high θ and zero θ, and develop an empirical formula based on experiment for the "transition" region lying between the two, such as that shown by a chain dashed line in Fig. 36.

The sideforce and lift provided by plane net specimens that have the axes of the meshes located asymmetrically relative to the stream have also been studied in detail.

Analogous methods have been applied to complete nets, and some full-scale drag measurements are compared with a partly empirical formula in Fig. 37. This case refers to a net of varying mouth area, due to varying headline height. It will be seen that there is a considerable component of drag even at very small mouth area, together with a component that increases fairly slowly,

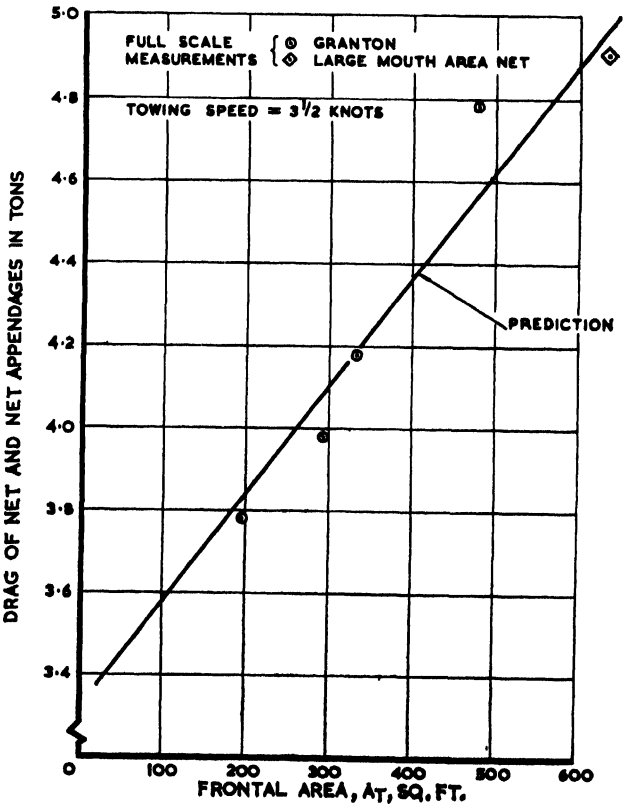

Fig. 37. Variation of drag of net and net appendages with mouth area.

and almost linearly, with mouth area. It is believed that when a net mouth is opened so wide that setting angles of 45° or more occur, the drag may cease to increase any further but such large setting angles are unlikely to be acceptable for structural reasons. The

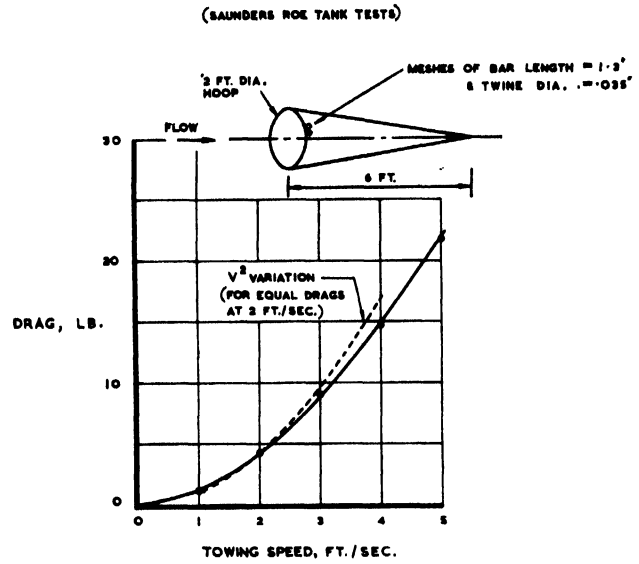

Fig. 38. The resistance of a simple conical net of fixed frontal area (Saunders Roe Tank Tests).

data in Fig. 37 all refer to a single towing speed. If a simple conical net of fixed mouth area is towed at varying speeds, the resistance increases almost as the square of speed, as shown in Fig. 38. A practical net tends to reduce headline height as speed increases, however,

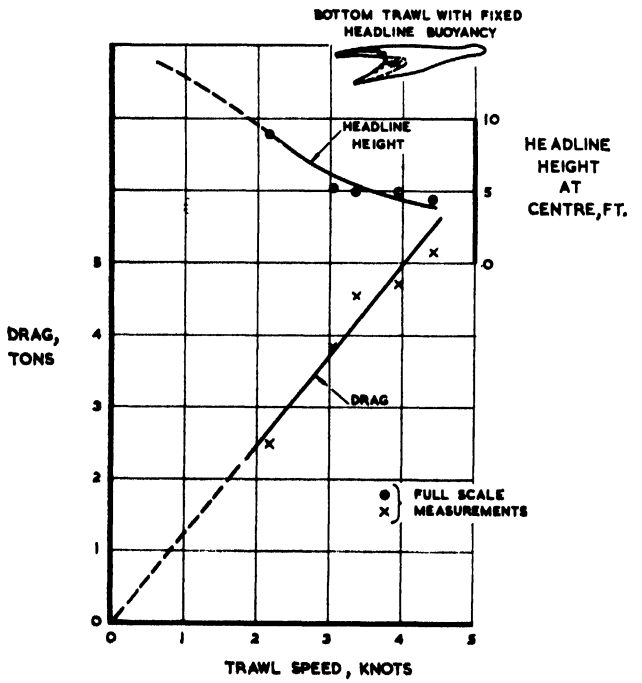

Fig. 39. The resistance of a practical bottom trawl net with frontal area reducing as speed increases.

and the effect is to give an increase in drag that is much more nearly linear with speed (see Fig. 39). This has already been mentioned in connection with Fig. 10.

Headline height can, of course, be increased by increasing the number of headline floats or by using dynamic lifters. A method has been developed for calculating headline height from a knowledge of the characteristics of the headline lifters, the details of the leg system, and the design of the net wings. This makes it possible to provide a bottom trawl of fixed mouth spread but with any required height, up to say, 20 ft., without greatly increasing towing power requirements.

3. CONCLUDING REMARKS

In this paper it has only been possible to give a limited descriptive and selective account of the extensive theoretical and experimental investigations that have been made into the fluid dynamic and engineering principles on which the scientific design of trawl gear depends.

The author claims that the requirements for a distant-water trawl, given at the beginning of the paper, have been met, and at the same time that a basic theory has been provided from which gears having other requirements can be designed. Furthermore the theory can be used to analyse and predict the mechanical and structural properties of other proposed or existing gears. However, it would be disingenuous to suggest that the achievement of given engineering objectives will necessarily catch more fish.

It would appear that a close co-ordination between gear engineering design and fish behaviour projects is necessary to achieve the type of gear that is efficient from an engineering point of view, and also takes adequate account of fish behaviour. For example, determination of an optimum relationship between size of otter board and size of net may not depend merely upon finding which arrangements require relatively low towing powers, and suit the nature of the seabed at the fishing grounds under consideration.

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continued on page 181

Some Comparative Fishing Experiments in Trawl Design

Abstract

A series of fishing tests was made to compare the relative merits of a large lightweight wing trawl and a smaller and stronger otter trawl, both nets suitable for a 180-hp ship. At first the comparisons were made with the wing trawl skimming just clear of the ground and the otter trawl in close contact with it. In presenting the results, the author describes fully the methods he considers necessary for the treatment of comparative fishing data. Though in some areas and at some times the big wing trawl skimming the bottom did very well, it was at other places and times outfished by the small trawl in close contact with the bottom, even for species such as whiting. A second series of tests was done with the wing trawl also in close contact with the bottom. It now outfished the small trawl steadily but suffered repeated damage when the small trawl did not. The general conclusion is drawn that the wing trawl is about the biggest (70-ft headline, 85-ft footrope) and the thinnest twine (210/30 nylon) that can reasonably be used by that power of ship. A case is made for carrying on board both a large wing trawl and a small strong otter trawl for use on hard ground. Another series of experiments was done to find the best mesh size for the square, wings and belly of the net. The conclusion was drawn that, in the northern North Sea, fishing for haddock and whiting, more of the net should be in 3½ inch mesh (89 mm), i.e., smaller mesh than is present commercial practice, particularly along the sides.

Quelques essais de pêche comparative de chalut

Résumé

Une série d'épreuves ont été faites pour comparer la valeur relative d'un grand chalut léger à haute ouverture et d'un petit chalut de plus forte construction, tous deux de dimensions convenant à un bateau de 180 c.v. Les premières pêches comparatives furent exécutées avec le chalut à grande ouverture effleurant le fond et le petit chalut en plein contact avec le fond. En présentant les résultats, l'auteur décrit les méthodes qu'il consideré comme nécessaires pour évaluer l'information obtenue par des pêches comparatives. Bien que dans certains lieux et en certaines occasions le chalut à grande ouverture effleurant le fond pêchait très bien, le petit chalut qui pêchait en contact avec le fond capturait plus de poisson en d'autres lieux et occasions, même pour des espèces comme le merlan. Dans une seconde série d'épreuves, le chalut à grande ouverture opérait aussi en contact avec le fond. Il capturait alors constamment plus de poisson que le petit chalut mais était endommagé très souvent tandis que le petit chalut ne l'était pas. On peut conclure qu'un filet de 21 m de ralingue supérieure et 26 m de ralingue inférieure, construit de fil le plus fin (210/30 nylon), est le plus grand chalut qu'on peut utiliser raisonnablement pour ce type de bateau. Il est conseillé d'avoir à bord d'un chalutier de ce type, un chalut léger à grande ouverture pour les bons fonds et un petit chalut robuste pour les fonds durs. Une autre série d'expériences était effectuée pour déterminer la meilleure grandeur de mailles pour les différentes parties du chalut. La conclusion fut que, dans le nord de la Mer du Nord, pour la pêche de merlans et d'églefins, plus de filet en mailles de 3,5 pouces (89 mm) devra être construit, c'est-à-dire avec des mailles plus petites que celles utilisées actuellement dans la pêche commerciale.

Ensayos de pesca para comparar formas de artes de arrastre

Extracto

S realizó una serie de ensayos para comparar las ventajas e inconvenientes de un arte grande de pernadas muy altas y otro más pequeño y robusto de puertas, ambos a propósito para un barco con motor de 180 hp. Al principio, las comparaciones se hicieron con el arte de pernadas altas pasando por encima del fondo y el de puertas en contacto con él. Al presentar los resultados el autor describe con toda clase de pormenores los métodos que considera necesarios para el tratamiento de los datos de pesca comparativa. Aunque en algunos caladeros en diversas ocasiones el arte de pernadas muy altas que pasaba por encima del fondo dio buenos resultados, en otro lugares y momentos el arte pequeño en contacto con el fondo pescaba más, incluso especies como la merluza americana. Se realizó una segunda serie de ensayos con el arte de pernadas muy altas en contacto con el fondo. El resultado fue que pescó más el arte de puertas pequeño pero sufrió repetidamente averías que el otro no tuvo. La conclusión general es que el arte de pernadas muy altas es el mayor (relinga superior de 70 pies e inferior de 85 pies) y el de hilos más finos (nylon de 210/30) que puede emplear un barco de esa fuerza. Se dan razones convincentes para llevar a bordo un arte de pernadas muy altas y otro más robusto y pequeño de puertas para emplearlo en fondos sucios. En otra serie de experimentos se determinó el tamaño de mallas más conveniente para la visera, pernadas y vientre del arte, llegándose a la conclusión de que, en el septentrión del mar del Norte cuando se pesca eglefino y merluza americana, una mayor proporción de la red debería ser de malla de 3,5 pulgadas (89 mm), es decir, más pequeña que en la actualidad, particularmente en las secciones laterales.

by

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SIMPLY to make trawling gear bigger ought to increase its catching rate, but there are attendant disadvantages. The towing drag is increased, and there are extra problems in handling gear and increased liability to damage. The first is a hydrodynamic problem, the second a practical fisherman's problem and the third concerns strength of materials but also requires a knowledge of the seabed. Damage to netting does not only arise from its interaction with the seabed, it also arises from internal localized stresses resulting from inadequate design in the shaping of the net. A gain in fishing dimensions is often sought by the use of thinner twine, but unless stronger material is used a mere 10 per

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Curing long-span conductor oscillation. Engineering, 15 February, pp. 250, 251. 1963.

Acknowledgments

The author would like to give the fullest acknowledgment to the representatives of the White Fish Authority, the scientific personnel of the Fisheries Laboratories, and the many people in the fishing industry who have provided information and assistance. The full-scale development tests of gear, forming an important part of the investigation, have been made on the Fisheries Research Vessels, F.R.V. *Explorer* and R.V. *Ernest Holt*. Finally, the extensive published investigations of earlier workers in the field, especially the Japanese, Russians and Germans, have been used as starting points for some of the work described here.

cent advantage in twine diameter incurs a 20 per cent loss of strength. The stronger synthetics allow a useful strength gain with thinner twine and as important a mitigating factor as their increased wet knotted strength is the elasticity and ability to withstand shock loads, possessed by some of them. Increasing the mesh size is another way of keeping the drag down, but this may lead to poorer shepherding in the forward parts of the trawl and more escapes in the after parts.

This paper describes some experimental attempts to determine optimum net size, twine size and mesh size by comparing the catches of different trawls. Optimum size had of course to take into account the power of the trawler, in this case 180 hp.

(1) The purpose of comparing a small strong trawl against a much larger lightweight one was to assess the catch gain using a big net and to assess the factors limiting its use.

(2) The purpose of comparing nets, identical except for the different mesh sizes in their forward parts, was to narrow the range of choice in this most important feature of net design, even if only for one or two important species in localized areas.

Comparisons between two nets are like a series of football matches. Replays at different times and at different places lead to different results, and past form is no guarantee of the results of the next match. When doing comparative fishing tests on a research ship, where the attempt is made to measure every fish or else to sub-sample accurately, a great deal of data is accumulated. The condensing and presentation of this in meaningful form is not easy and, oddly enough, considering the large amount of data to start with, there rarely seems to be enough processed material at the finish to be certain of the conclusions that can be drawn from it. When comparative fishing with one boat only, the variability in catch between hauls demands a large number of replicates, which are seldom achieved! In short, most answers provided by comparative fishing are provisional.

Any net catches a biased sample from the sea. It will be better at the capture of some species than of others and quite apart from codend mesh size, it may tend to take bigger rather than small fish or *vice-versa*. In tests like this the codend mesh size is made small enough to take everything of interest. Alternatively, the codend is fitted with a small meshed cover. The objective of this type of comparative fishing experiment is to discover the nature and degree of the main bias and to look for explanations of it.

Wing trawl and otter trawl

The Vinge or wing trawl with its forked wing ends is used primarily by the continental cutters as a herring trawl and it was as such that it was first used on our research vessels, *Clupea* and *Mara*, though it soon became obvious to ourselves and others that it had potentialities for demersal species as well. It is a big and rather complicated net of lightweight material. When rigged for herring trawling, the net floats (i.e., flotation outweighs the sinkers and altogether the net has positive buoyancy). The long danleno poles are weighted to hold the bottom, while the footrope rides clear of it, save for the loosely hung bights of chain, which must be just polished at the bottom of the bight. When fishing for whiting and haddock, the danleno poles are seldom used.

It soon becomes obvious that some fish are escaping under the footrope; the temptation is to bring it close to the ground. The dilemma is spotlighted in Fig. 1, taken

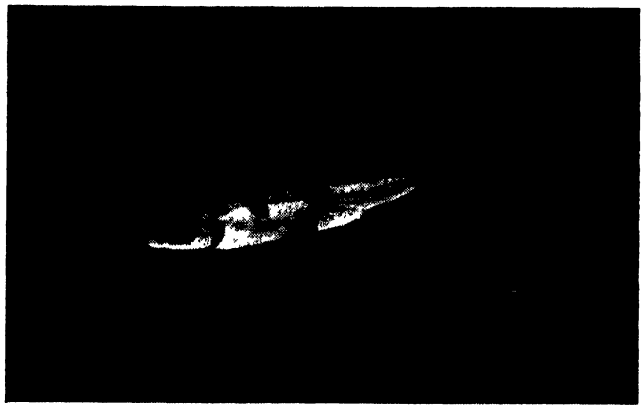


Fig. 1. Haddock on stony bottom, unfishable by light trawls.

from a flash camera mounted on the trawl headline. Haddock are very often as close to the bottom as this and their chance of escaping under a footrope skimming one foot clear of the bottom is good. Put the light footrope of a lightweight wing trawl on to such a bottom, and the net will be severely damaged.

In the first series of tests the wing trawl (Fig. 2) was kept buoyant, while the otter trawl (on the left of Fig. 3) was in close contact with the bottom. The tests were confined to daylight and to good ground. The nets were tested at the same engine power so that the big net was towed slightly slower in the ratio 3·4 to 3·6 knots. Headline heights and spreads are given later.

Method of presentation

(a) Circles are used to illustrate species composition. The overall area of the circle represents the total number of fish caught on an hourly basis and it is segmented by proportion into species. Note that this does not give the relative commercial value of the catches, because a small fish counts as a unit here the same as a big one, and some species have a greater market value than others. Some of the more interesting examples are shown in Fig. 4. The circles give the average catching rate over a period of several days fishing in each area.

(b) Histograms are used to show the number of fish of each species caught in each one-hour haul. Looking at these gives some visual idea of the quality of an experiment. It shows how many hauls were made, whether the gear was changed over reasonably often, the variability from haul to haul and whether the average catching rate and species composition as shown by the circles is likely to have been biased by one or more hauls greatly

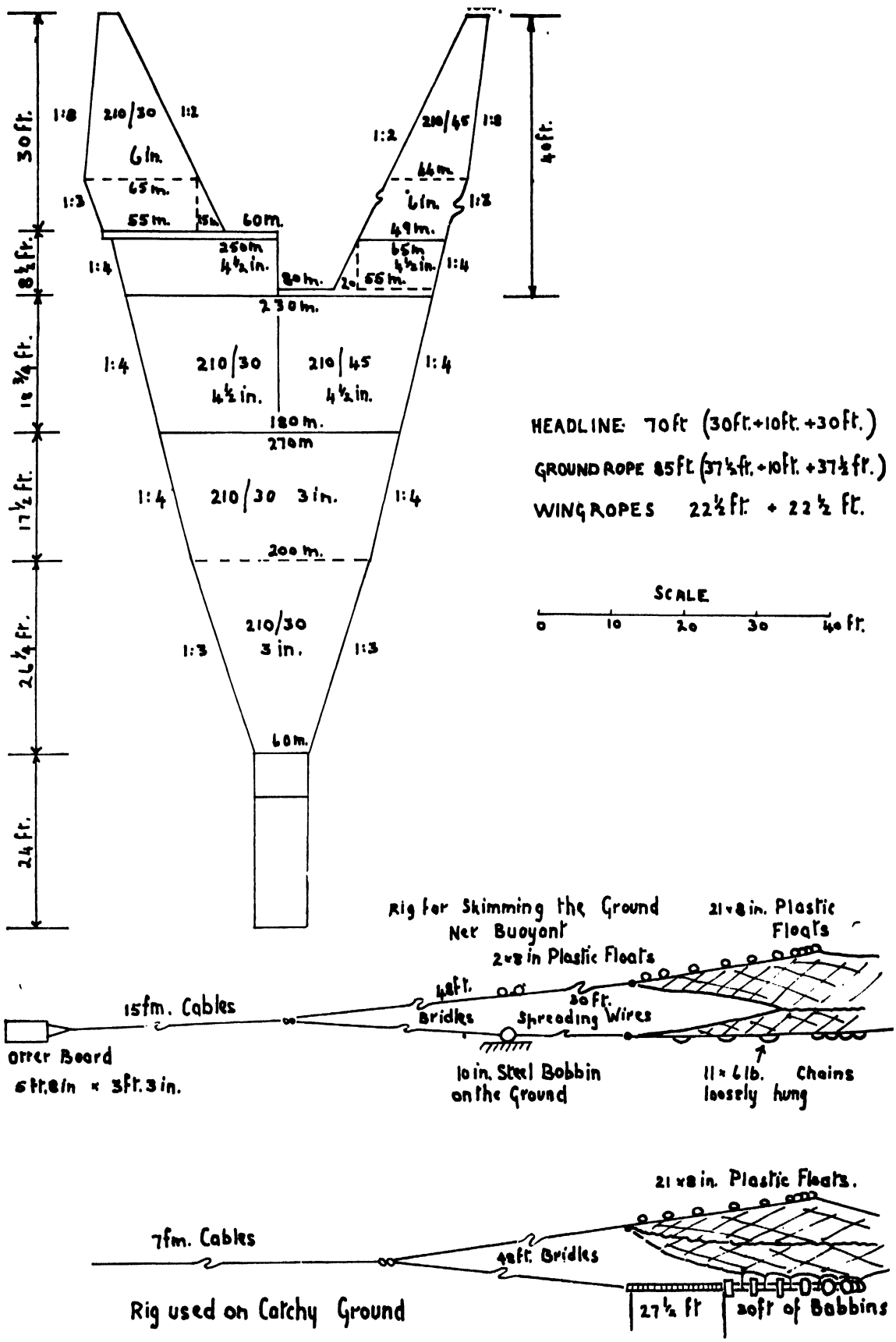


Fig. 2. Wing trawl.

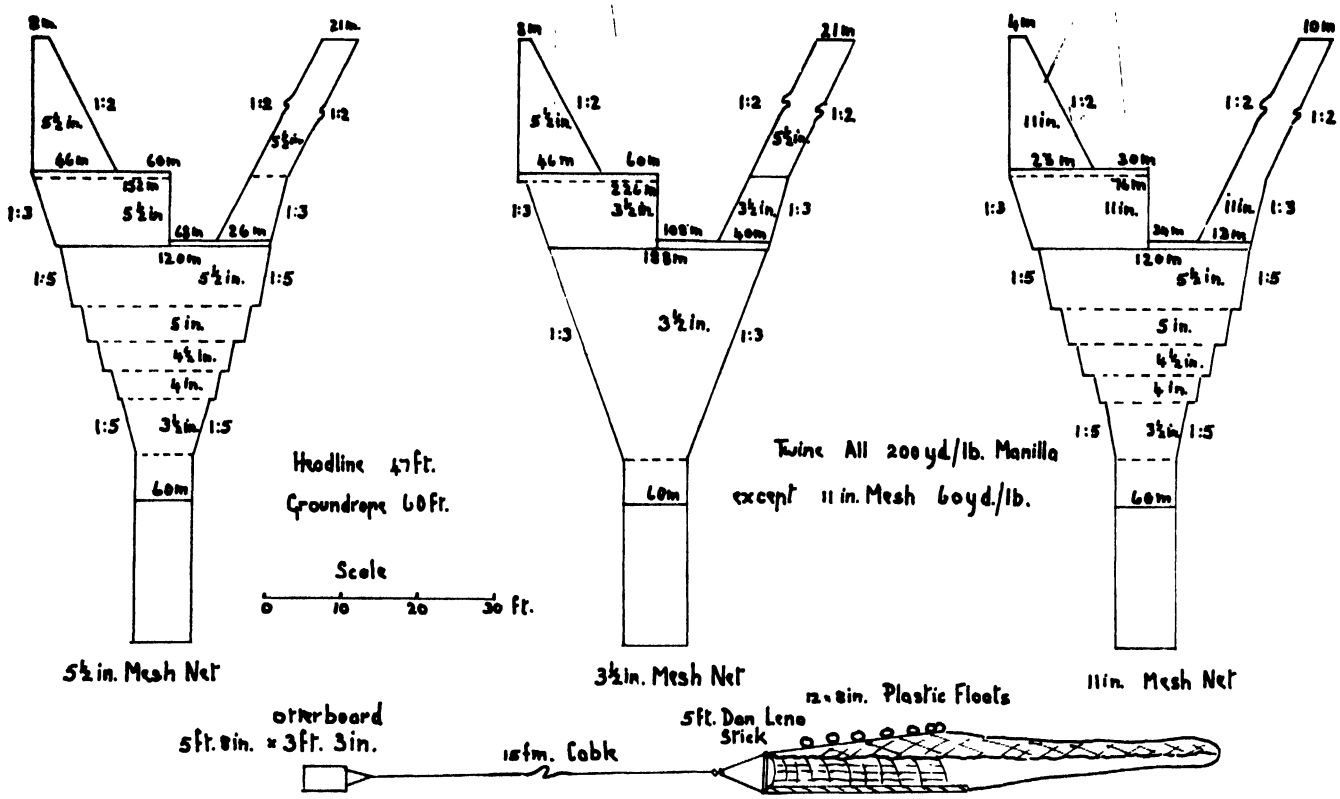


Fig. 3. Small otter trawls, with different mesh sizes in their forward parts.

larger than the others. Histograms are shown in Figs. 5, 6 and 7. For convenience in presentation, their heights are shown logarithmically, which means that the net which is doing better is doing even better than appears at a glance.

(c) Length composition curves show how the catch of each species is divided up into the numbers appearing at each centimetre length. This can be done for every haul, but results are usually summed for groups of hauls

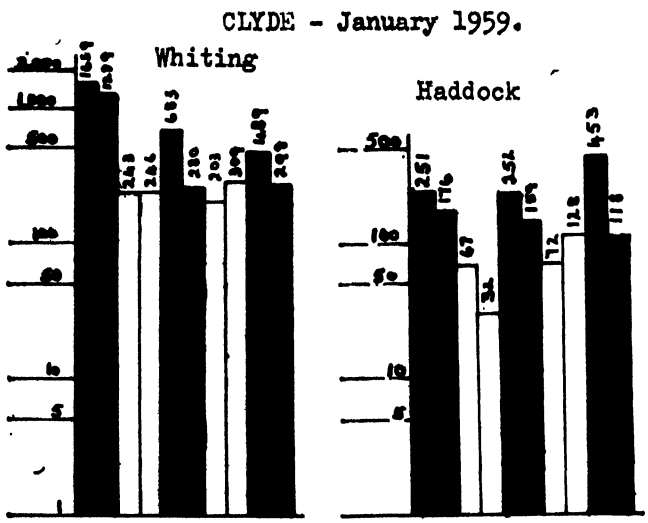


Fig. 5. Histograms, haddock and whiting, Clyde, January 1959. Plain column indicates wing trawl. Black column otter trawl.

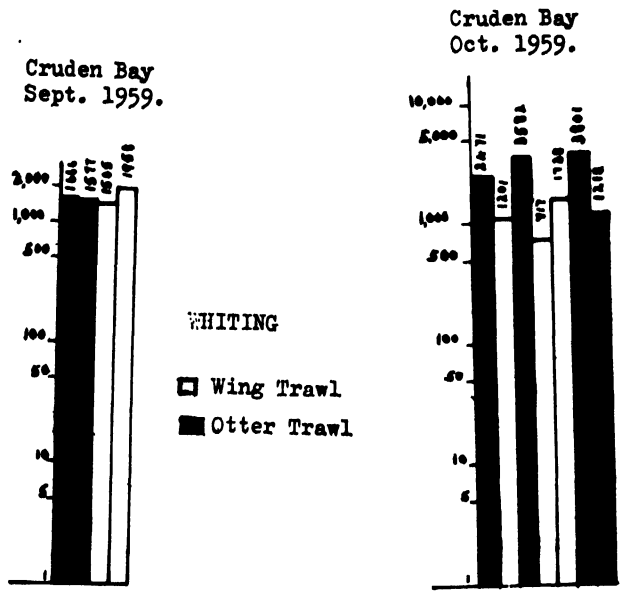


Fig. 7. Histograms, whiting only Cruden Bay, September and October, 1959.

in one area at one time. There are two ways of presenting length composition curves each having advantages. The length composition can be shown proportionally for every 10,000 fish caught with each trawl and this is the best way of showing the bias in sampling between the two trawls irrespective of quantity caught, or it can be

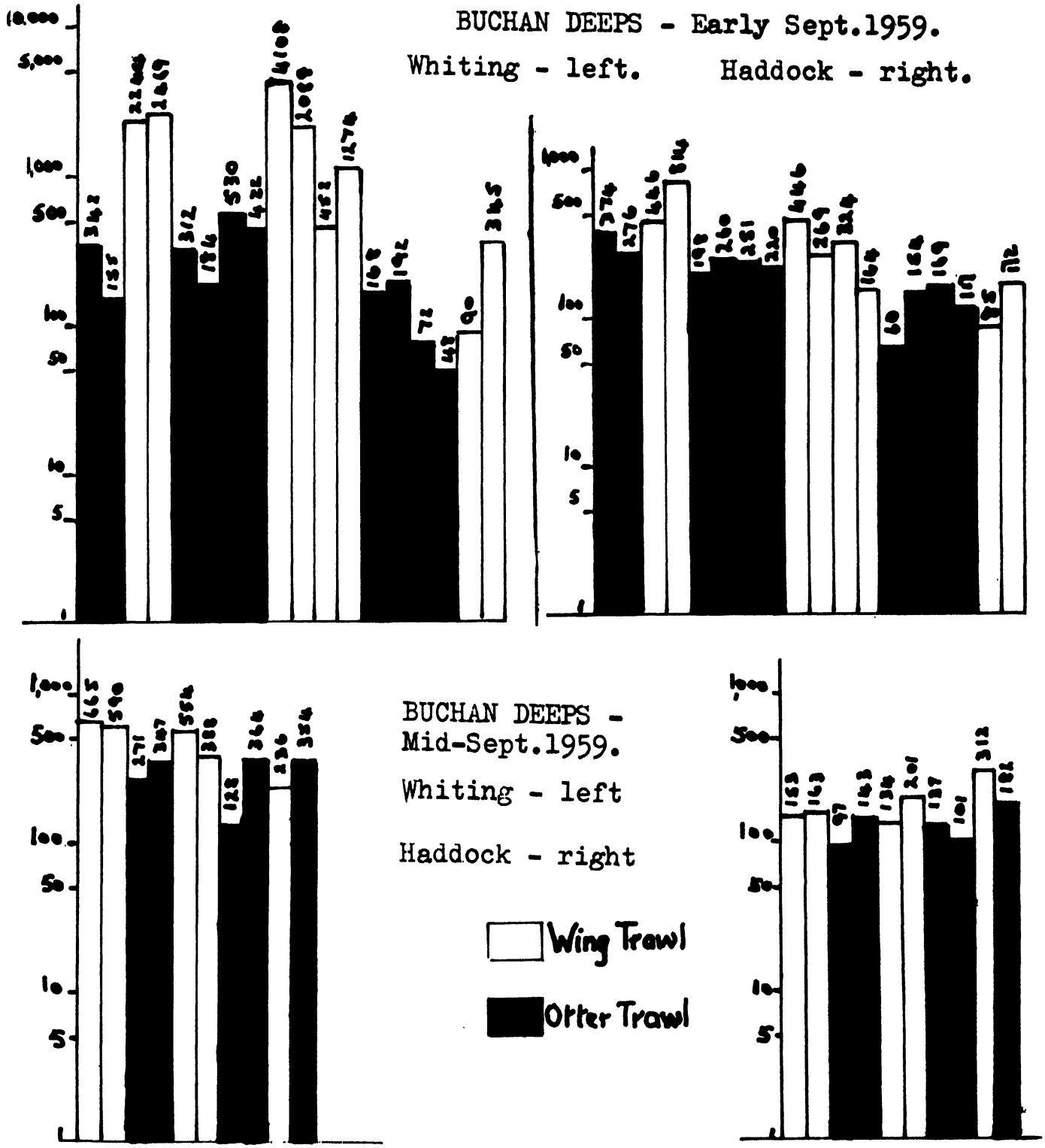


Fig. 6. Histograms, haddock and whiting, Buchan Deeps, early and mid-September, 1959.

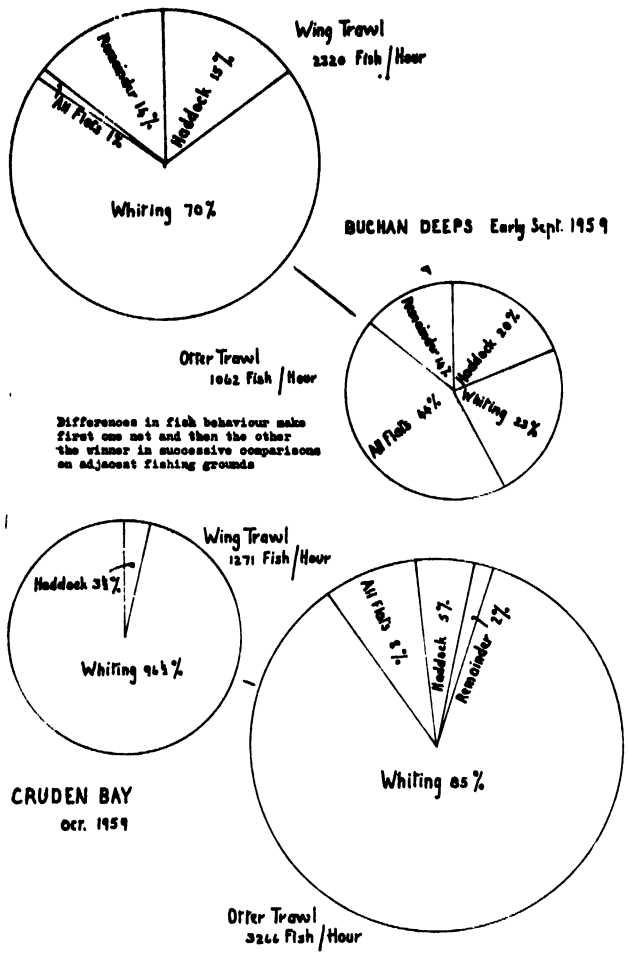


Fig. 4. Catch composition. Wing trawl buoyant. Otter trawl on ground.

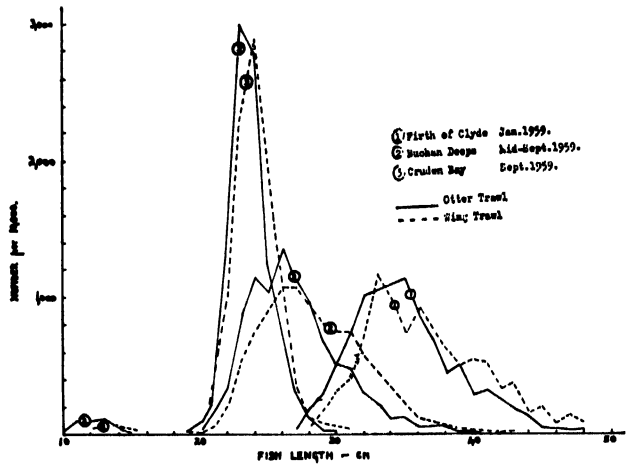


Fig. 8. Length composition per 10,000 fish whiting, Clyde, Buchan Deeps and Cruden Bay, 1959.

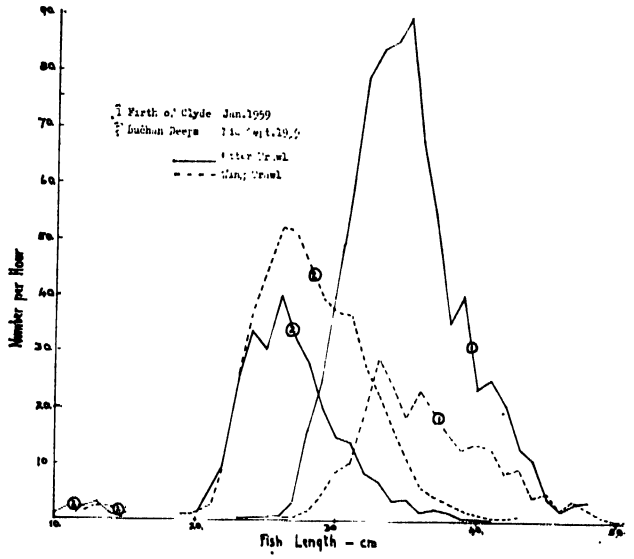


Fig. 9. Length composition per one hour fishing, whiting, Clyde and Buchan Deeps, 1959

shown on the basis of the hourly catching rate, which shows not whether one trawl caught proportionally more big ones, but whether it actually caught more big ones. The number of graphs is too large to present them all here. All showed bias in the same general direction and a selected few are shown in Figs. 8 and 9.

Discussion of the test results

The wing trawl, skimming clear of the ground, has a more restricted range of species appearing amongst its catch. Although it can at times outfish a small otter trawl, particularly for whiting but to a lesser extent for haddock also, it does not always do so and is sometimes quite heavily outfished even for these species, presumably when they are in close proximity to the bottom. This is the essential point to be taken from Fig. 4.

The length composition curves (Fig. 8) show that the wing trawl tends to take proportionally more of the bigger whiting and the same was true for haddock to a lesser extent. The curves in Fig. 9 show that even when outfished in the Clyde the wing trawl took nearly as many large whiting and when it outfished the otter trawl in the Buchan Deeps, it took no more small ones. The bias is noticeable even in the sampling of the baby brood. There were at this stage of the experiment a number of possible explanations, some of which are ruled out later. They may be sought in differences in fish availability to the nets, differences in avoidance or differences in mesh selection.

(i) The smaller fish may keep closer to the ground thus being more likely to escape under the ground-rope of the wing trawl.

(ii) If the bigger ones swim higher up, they may be more liable to capture by the wing trawl with its considerably greater headline height, in the ratio of about 8 ft as against 5 ft.

(iii) The wing trawl has a greater headline spread than the otter trawl in the ratio 35 to 25 ft, so it is possible that the bigger and faster-swimming fish have a better chance of being shepherded from the region of the wings into the path of the bag, while the smaller ones are more likely to pass through the wings. The thinner twine used

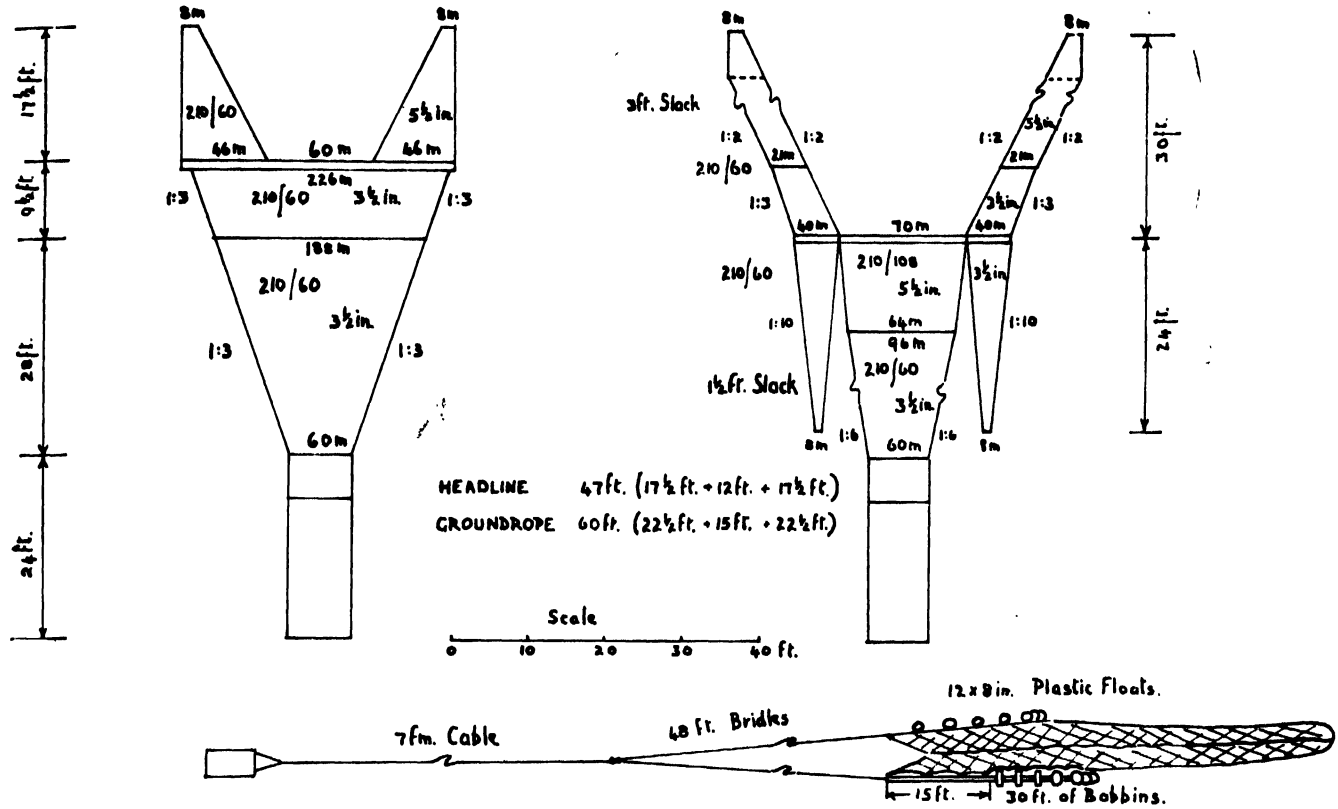


Fig. 10. Small hard ground otter trawl.

in the wing trawl might enhance such an effect.

(iv) The bigger faster-swimming ones may find it easier to avoid the smaller net.

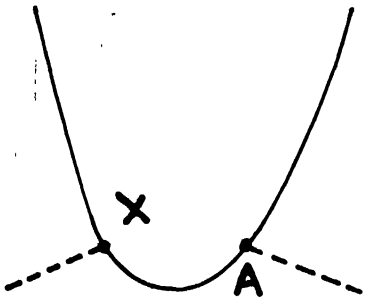
(v) It may be that more small ones succeed in escaping from the lengthy bag of the wing trawl before reaching the codend.

A new test

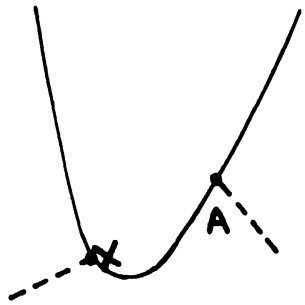
It seemed that something more might be learned if the two nets could be fished, both with negative buoyancy and with the same groundrope firmly on the bottom. Since the wing trawl is quite vulnerable and ought to be kept clear of the ground, it was decided that both nets should be rigged with a groundrope comprising 14 in rubber bobbins in the bosom and 12 in rubber bobbins in the bunts. (See Fig. 2 for the details of the large trawl and Fig. 10 for the details of the small trawl.) Note that, in this series of tests on rougher ground, the forked wing ends of the big trawl were sewn up to make the net less liable to snag on the bottom, while the wing ends of the small net were opened out.

The ground chosen for this comparison was catchy in places without being really rough. In all 28 hauls were made on this ground with each net, and on five the large trawl was seriously damaged. Working on a commercial basis, it would not have been possible to carry on using it on that ground, and it was only possible in this instance by having net riggers ashore mending steadily. The small trawl was scarcely damaged. It is now suspected that, even without the net snagging on the bottom, sudden change of shape of the groundrope as it meets an obstruction may burst the belly of a lightweight net, even though the bobbins later surmount the obstacle; and indeed, when they do surmount it and rush to re-assume an

Fig. 11. Elongation of the meshes where the lower wing joins the belly bosom.



Groundrope Approaching Snag



Groundrope Strikes
Snag and Distorts.

Fig. 12. Groundrope meeting obstacle.

even towing position, the resulting localized stresses may cause further tearing. Fig. 11 although photographed on a heavy Granton trawl, shows the elongation under localized tension of the meshes behind the groundrope quarter (position A in Fig. 12) such as occurs in most nets. Suppose now the groundrope encounters an obstacle at X; the groundrope rapidly changes shape and A moves rapidly forward increasing the localized stress. It is clear that a lightweight net is more liable to rupture than a stronger one, that nylon with its ability to withstand shock loads is a useful material in such situations and that prestressing, due to inadequate design in such an area of net liable to be shock loaded, is a source of weakness. Means of relaxing these localized tensions have been discussed elsewhere. (Dickson 1961, Garner 1962.)

Further discussion of test results

The species composition, the catch histograms and the length distribution curves for the new tests with the groundropes of both trawls firmly on the bottom are shown in Figs. 13, 14 and 15.

The species composition for the large wing trawl is now quite different from what it was before. Flatfish are now making a significant contribution to the catch. The catch histograms show a favourable result for the large trawl on this occasion, but remember it was at a cost in net damage that would have been prohibitive commercially.

The bias in the length distribution curves is in the

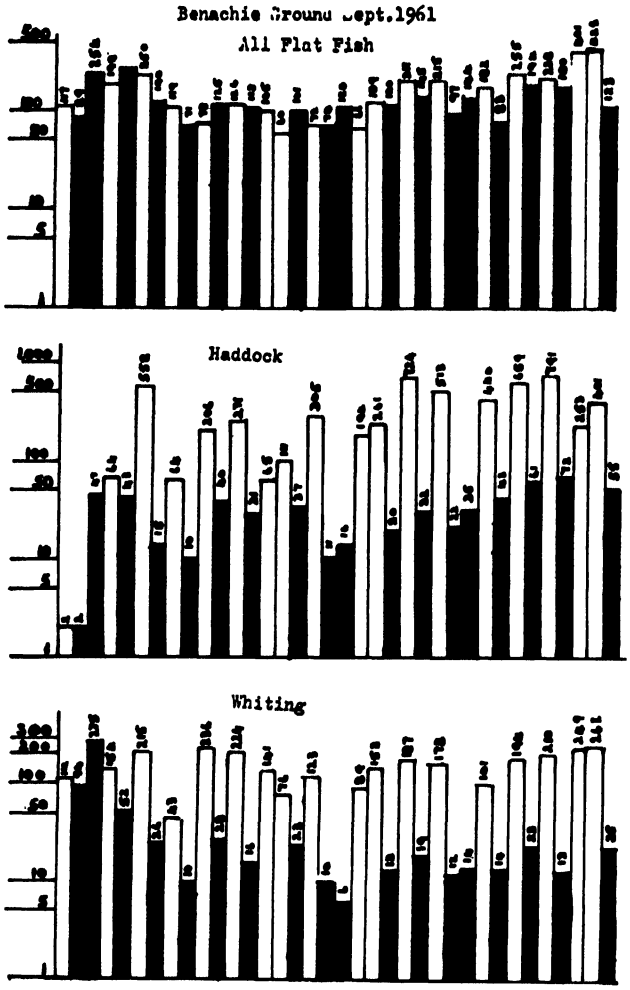


Fig. 13. Histograms, whiting, haddock and flatfish, Benachie Ground, September, 1961, plain white column is wing trawl and black is otter trawl.

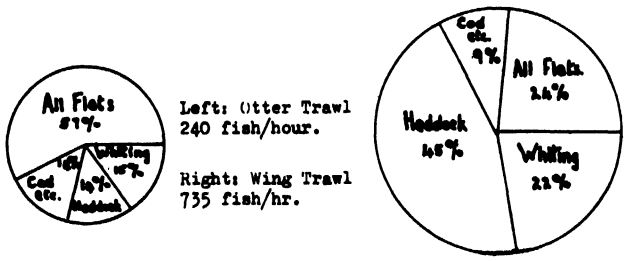


Fig. 14. Catch composition: both trawls rigged with the same bobbin groundrope, Benachie Ground, September, 1961.

same direction as when the wing trawl was buoyant. The possible reasons previously given for this can now be reviewed. No. i is ruled out because there is now no reason to suppose that small fish escape more readily under the groundrope of the wing trawl as the groundrope was the same for both nets. No. ii seems unlikely as a general reason since the same bias appears to be present in the case of flatfish, which are less likely to be stacked so that big ones are more susceptible to capture by a high headline net.

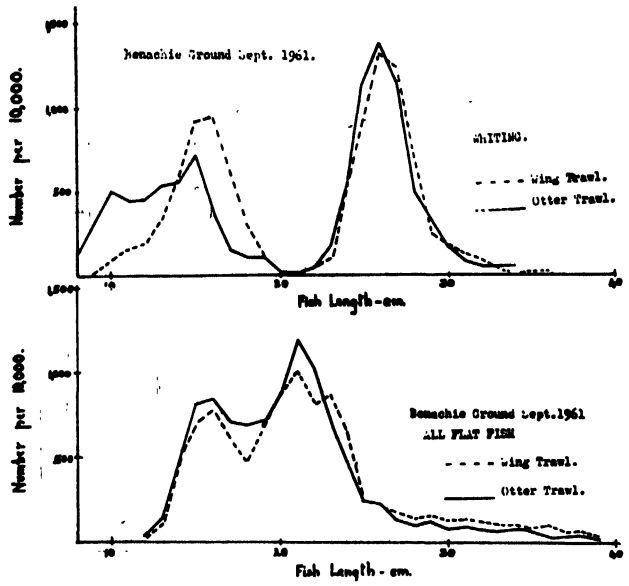


Fig. 15. Length composition per 10,000 fish, whiting and flatfish, Benachie Ground, September, 1961.

The general conclusion drawn from the whole series of tests is that, while a large lightweight wing trawl can be very effective at times, its use even when rigged with bobbins is limited to fairly good ground. It seems a sensible practice to equip ships with both kinds of bottom trawl or at least to hold them ashore in readiness against the seasons and the fisheries where each type is required. There is no such thing as a wonder trawl which is a winner in all circumstances.

If two such nets are used it is necessary to make the nets in synthetics so that the one does not rot while the other is in prolonged service. This at least is now the practice adopted for our research trawlers. The tests also set limits to the sizes of twine that it was found reasonable to use in the large and small nets towed by a ship of 180 hp. The small net, made in 210/60 nylon twine and with 210/108 nylon in the front part of the belly, is a very strong net suitable for using on unknown rough ground. The trawl is then rigged with bobbins of course. The big wing trawl was found to be strong enough for herring trawling with the top and lower wings, the square, batings and belly all made in 210/30 nylon, but when working for demersal species it was found better practice to make the lower wings and belly in 210/45 nylon.

The otter boards, suitable for that size of ship, only spread the headline of the wing trawl to half the headline length; it follows that there is not much point in making the net any bigger.

Having thus reached acceptable upper and lower sizes for the nets and the twine of which they should be made (Figs. 1, 2 and 3), the next thing to look at was how the mesh size should be distributed in the plan of a net.

Mesh size distribution

The usual practice in North Sea nets is to grade the mesh size from 5½ or 5¼ in in the wings down to the regulation size for the codend. The grading is usually done in the belly. With hand braiding it is still a common practice to change the mesh size in several steps without putting in any gaining meshes across the join. As the tendency towards machine made netting grows, so does the tendency to have as few mesh sizes in the net as possible, and this necessitates gaining meshes in the joining rows. In the ports where haddock and whiting are the most important species sought, it is a common practice to have the square and upper body in 3½ in mesh and to grade the mesh size in the lower belly only. Thus apart from the top wings, the roof of the net is in small mesh while much of the side formed by the lower wings and belly is still in large mesh.

With haddock and whiting as the species sought, the tests were to try and find out whether it was advantageous to carry the small mesh further forward and to include the sides of the net. On the other hand it might be possible to have the square, top and lower wings in much larger mesh. To try this a net was made with these parts in 11 in mesh; but, so that it would fish at about the same dimensions as the 5½ in mesh net, the twine size of these parts was also doubled in diameter. This makes a very strong net. The specifications of the 3½ in mesh and the

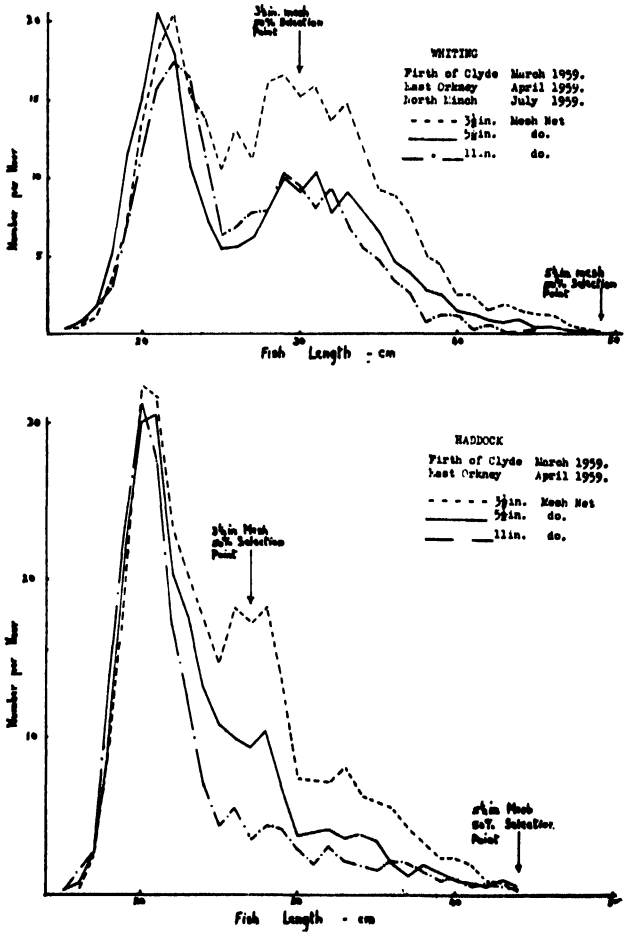


Fig. 17. Length composition per one hour fishing, haddock and whiting, Clyde, East Orkney and North Minch, 1959, 3½ in., 5¼ in, and 11 in mesh nets.

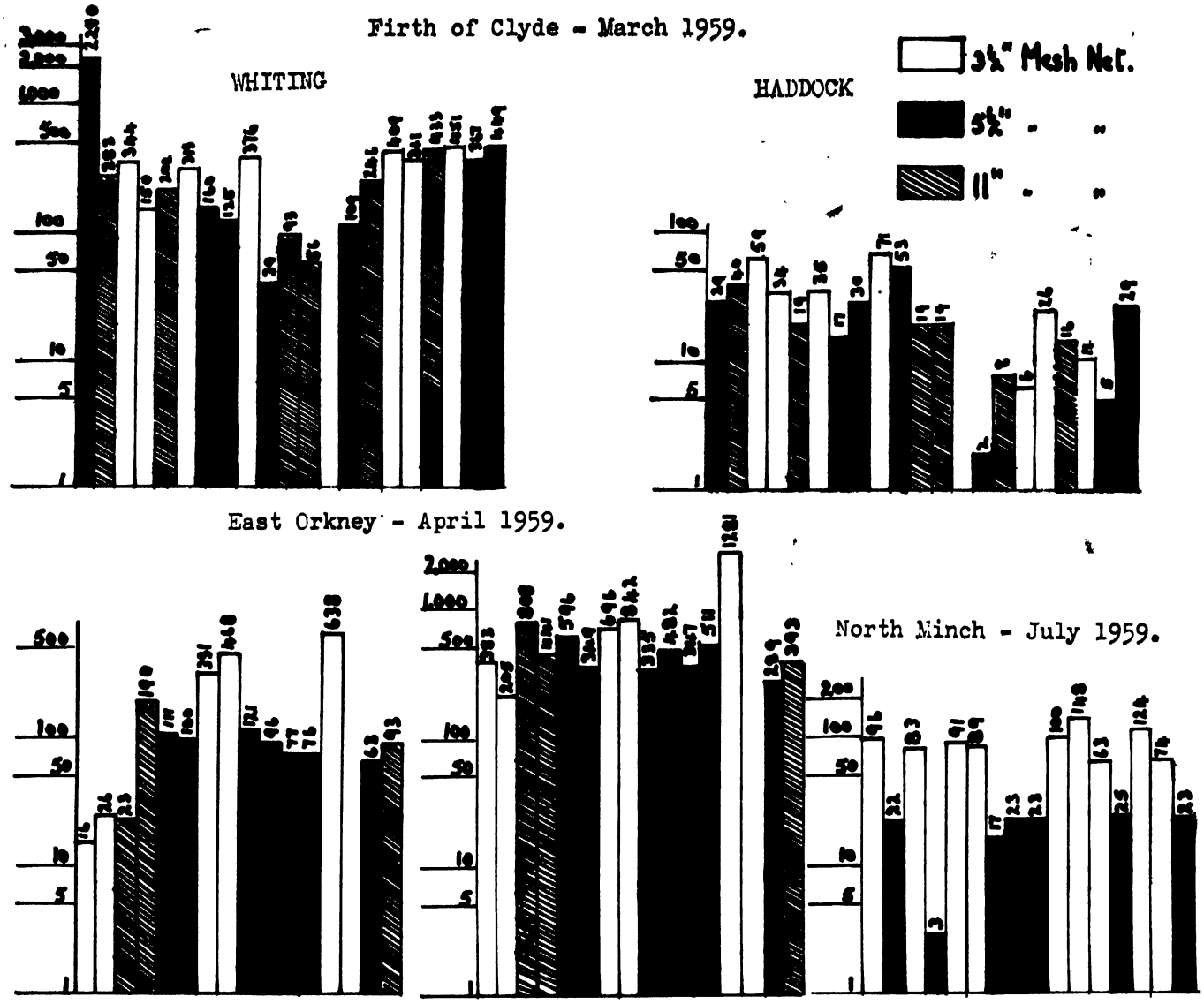


Fig. 16. Histograms, haddock and whiting, Clyde, East Orkney and North Minch, 1959. In the lower histogram the bottom left and right refer to whiting and the centre to haddock.

11 in mesh net are given in Fig. 3 along with that of the $5\frac{1}{2}$ in mesh net. As compared with the $5\frac{1}{2}$ in and the 11 in, the $3\frac{1}{2}$ in mesh net loses a little in headline spread, when being towed. It probably loses a little in speed too because of the increased net drag.

Discussion of mesh size results

The catch histograms are shown in Fig. 16 and the length composition curves in Fig. 17. These curves are lumped together from others, all of which showed the same general bias though taken in different areas. The surprising thing is how little difference there seems to be between the catching rates of the three nets for small fish and how the gain in carrying the sides and roof of the net forward in $3\frac{1}{2}$ in mesh is for the larger faster-swimming fish. Even some marketable fish can, of course, pass through a $3\frac{1}{2}$ in mesh net. The selection factor (defined as the ratio of fish length to mesh lumen length at which 50 per cent of the fish escape through the meshes of a codend and 50 per cent do not) may be taken as 3·3 for haddock and 3·7 for whiting. Allowing for the size of the knot, the lumen size of $3\frac{1}{2}$ in mesh is 82 mm, so that haddock as big as 27 cm and whiting as big as 30 cm could be expected to escape; similarly for $5\frac{1}{2}$ in mesh the haddock and whiting sizes are 44 cm and 49 cm.

Again an explanation of the length composition curves is uncertain but the bias is in the wrong direction for it to have been due to mesh selection in the forward parts of the trawl. Nor does difference in availability seem likely with the fishing dimensions of the three trawls so similar. This leaves difference in avoidance as the most likely explanation, possibly the bigger faster-swimming fish putting on a spurt to carry them out through the square and bunts of the large mesh nets.

continued on page 191

Development of an Improved Otter Trawl Gear

Abstract

Experiments have shown that the traditional trawl gear has several shortcomings. The trawlboards tend to dig unevenly into the bottom, following a zigzag course, thus causing constant changes in the net opening; the net shows bulges during operation which causes gilling of the fish; the waterflow inside the net is not evenly distributed, and is much slower than the towing speed, which causes turbulence. Studies of the net's behaviour at relatively high towing speeds led to an improvement in the design of the gear. In this paper the author gives details of the construction of a four-seam high-opening trawl and of the concave trawlboards employed. Experiments conducted with this gear showed that the difference between the waterflow inside and outside the net was reduced to 0.3 kn. at a towing speed of 4.5 kn. This design has now been adopted by trawlers in the East China Sea.

Etude du nouveau dessin d'un engin de chalut a plateaux

Résumé

Les essais ont montré qu'il existe plusieurs défauts aux engins traditionnels du chalut. Trop souvent les plateaux s'enterrent au fond provoquant une course instable et des changements fréquents dans l'ouverture du chalut; le filet se bombe et les poissons s'emmaillent. Le cours de l'eau à l'intérieur du chalut n'est pas uniforme et beaucoup moins rapide que la vélocité du remorquage ce qui entraîne la turbulence. Après étude du comportement du chalut ò des vitesses relativement élevées, on a dessiné de meilleurs engins. L'auteur donne des détails sur la construction d'un chalut à quatre coutures et à grande ouverture, ainsi que sur les plateaux de forme creuse employés. Les essais effectués avec cet engin ont démontré, que la différence entre le cours de l'eau à l'intérieur et à l'extérieur du chalut a été réduite à 0.3 noeuds, à une vélocité de remorquage de 2.5 noeuds. Ce nouveau dessin a été adopté dès maintenant, pour les chalutiers de la mer orientale de la Chine.

Fabricacion de mejores artes de arrastre de puertas

Extracto

Los experimentos han demostrado que los artes de arrastre tradicionales tienen varios inconvenientes; las puertas tienden a enterrarse en el fondo y causan cambios constantes en la abertura de la red; los paños se comban durante la pesca y los peces se enmallan; el flujo de agua dentro del arte no es uniforme y es mucho más lento que la velocidad de remolque, causando turbulencia. Como resultado de un estudio del comportamiento del arte a velocidades de remolque relativamente elevadas, se han proyectado artes mejores. El autor da detalles de la construcción de un arte de cuatro relingas de contorno, y gran abertura en altura, así como de las puertas cóncavas empleadas. Los experimentos realizados con este material demostraron que la diferencia entre el flujo de agua dentro y fuera de la red se redujo a 0.3 nudos a una velocidad de remolque de 4.5 nudos. Este arte lo emplean ya los arrastreros que pescan en el mar del este de la China.

by

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OTTER trawling and two-boat trawling are widely used in Japan and bottom trawling accounts for a major share of the total catch of commercial fishing.

The design and operation of the otter trawl introduced in 1904 has undergone many changes and improvements. The nets are made of synthetic twines, and V-D gear has replaced the traditional leg connection between net and board but, until recently, very little has been done to improve the general design and structure of the net itself.

The Fishing Boat Laboratory undertook a rational study of otter trawls and by February 1961 had completed the design and construction of a new modified trawler gear. This gear was tested from the newly-constructed *No.* 50 *Akebono-Maru*, 1,500 tons, 2,000 hp (Fig 1), of the Nichiro Fisheries Company and has since been fishing better than the old gear both on the large stern trawlers and medium-size side trawlers operating in the Atlantic and the Bering and East China Seas.

Defects of conventional otter trawls

The general shape of the trawl in action is such that it

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Whatever the reason, it does seem to be profitable, at least over this size range of fish, to carry the $3\frac{1}{2}$ in mesh fairly well forward in the top and sides of the trawl. The limitations on how far forward to bring it may be set by the amount of mending that has to be done and it seems likely that part of the belly at least should be in larger mesh to allow the bottom rubbish to fall through. The design currently favoured, and used by us for a North Sea hard ground otter trawl, is of the style shown in Fig. 10, though it need not be so small. As experiments along these lines are continuing, the design is not a final one but it synthesizes what has been learned to date. It is necessary to remember the limitations of these tests; they were done in daylight only; they cover only two species in a limited range of areas and not exhaustively even there.

A knowledge of fish behaviour, however acquired, helps in the design of trawls, but so does the fishing of trawls whose operational dimensions are known help in the understanding of fish behaviour, always provided that the trouble is taken to analyse the catch. The designing of nets with greater headline height, greater spread, etc., is a barren occupation unless the designs are put to the test of fish catching and put to the test in such a way that conclusions can be drawn.

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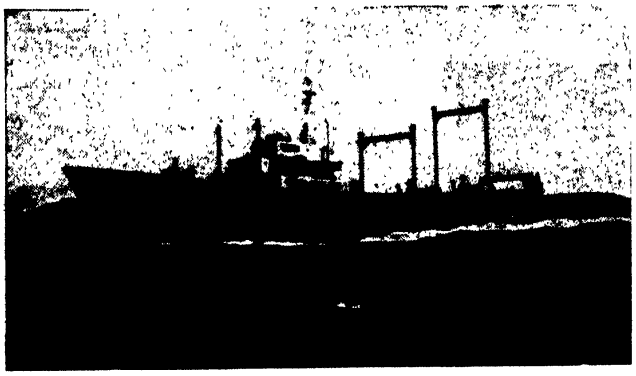


Fig. 1. No. 50 Akebono-Maru.

cannot readily be predicted by mathematical formulae. Nor can all the various factors which together compose its catching efficiency as yet be identified and defined or evaluated mathematically. No part of the gear, for instance, should interfere with the entrance of fish till caught in the codend; yet little is known of the precise reaction of the fish when it detects the gear either by sight, noise, smell or feeling. From long observations and experimenting with the gear, the author defined the trawl boards, bridles and the shape of the net as detrimental to efficient operation of the gear.

Trawl boards—These are dragged at a certain angle of attack over the bottom and should follow a straight course. This is, however, not always the case. Referring to Fig 2, every time the board cuts deeper into the sea-bottom the angle of attack forces the board outward in the direction of D. The warp tension eventually overcomes this ploughing effect, and the board moves back and beyond its original track so that the board follows a zigzag course. The zigzag movement is increased if the point of attachment of the warp is below the centre of the board since this causes the board to tilt out and plough deeper. Other important factors are the weight of the board and the width of the shoe.

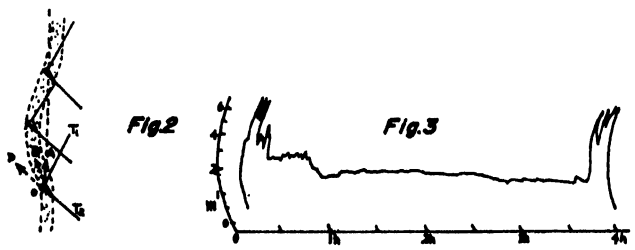


Fig. 2. Course of trawl boards.
Fig. 3. Headline-height changes with conventional-type trawl board during a four-hour haul.

With the two trawl boards so operating, the distance between the wing tips of the net is continuously changing. A narrowing of the net opening results in a relative increase of the headline height and these fluctuations can be clearly seen in Fig 3 which represent the net height changes of a conventional type trawl during a four-hour haul. The conventional height/length relation of 1:2 for trawl boards is not very efficient and, furthermore, flat plates do not give the best shearing power; all of which results in oversized boards.

Bridles—With the single bridle method, the legs from the wings are joined at the bridle or to a relatively small danleno. It is better to take full advantage of the board height to allow the wings to rise as high as possible, although this means using two bridles instead of one. The connection of board to net with two lines, furthermore, helps to steady vertically the board in action. For this purpose it is better to have a large value for the ratio H/L of the boards.

Shape of the net—Measurements have shown that conventional nets, during operation, take a bulky shape in the forebody with a pronounced narrowing in the after body (Fig 4). This billowing of the front part

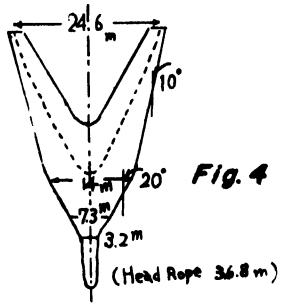


Fig. 4

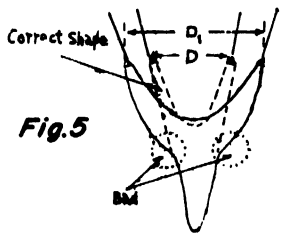


Fig. 5

Fig. 4. Shape of conventional net in operation.
Fig. 5. Two-boat trawl being towed at high speed with too great distance between boats.

of the net is caused by choking up of water which cannot flow freely through the net. Under such circumstances the waterflow to the codend is disturbed and causes gilling in the tapered body of the net. To avoid such gilling the mesh size is usually decreased which in turn causes even more resistance and turmoil which impedes capture.

Traditionally, bottom trawls are made of an upper and lower part laced together at the sides. With such structure it is difficult to distribute the waterflow evenly through all parts of the net and the rear part is therefore flattened out.

When a net is dragged at low speed, the net releases through its meshes an amount of water which is proportional to the area of the net opening and the towing speed; the waterflow inside the net is then the same as the towing speed. However, this is not the case at higher towing speeds. Measurements with flowmeters showed that in a 36·8m headline trawl towed at 3·5 kn speed, the waterflow had decreased to 2·7 kn already at a distance of only 2 m behind the footrope.

When the volume of water entering the net is greater than that which can be released by its webbing, a turmoil is started which at high speeds spills some water back through the net mouth, possibly taking with it some of the already caught fish. Pressure builds up inside the net which can prevent fish from entering and tends to

frighten strong swimmers away from the net entrance. The above is similar to what happens when a plankton net is towed too fast. To conclude, differences between waterflow in the net and the towing speed must be a minimum in a well-balanced trawl; the measurements performed on the conventional otter trawl showed a difference of 0.8 kn which points to poor water release.

Comparison with two-boat trawl

Since the net is towed by two vessels, the net opening is practically constant (both in horizontal and vertical direction) and can be regulated to the shape for which it was designed.

With this type of net the length to breadth relation is much bigger so that there is better water release. However, when the distance between the boats is exaggerated at high towing speeds, the net shows the same defects as those of the otter trawl (Fig 5). The vertical configuration of the webbing is much better than with the otter trawl.

Measurements of the waterflow inside a two-boat net gave 1.9 kn when towed at 2.3 kn. When large-mesh side panels were inserted at the waterflow inside increased

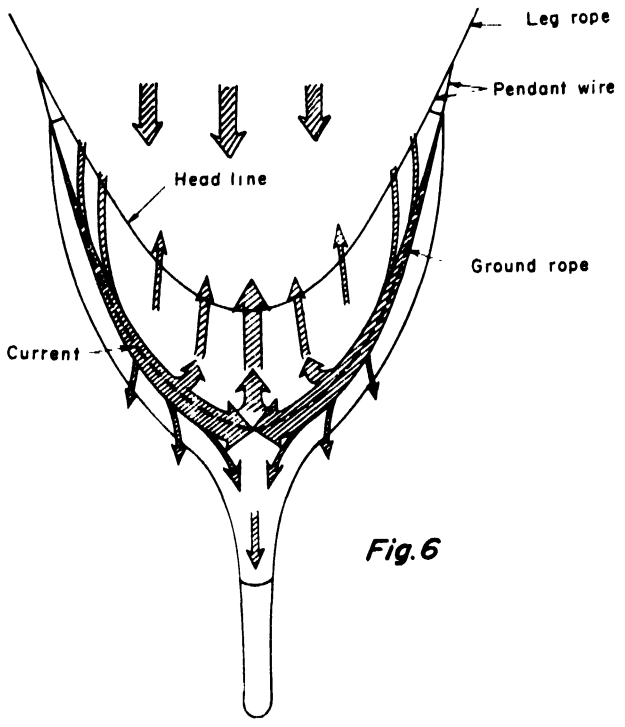


Fig. 6

Fig. 6. Pattern of water-flow in conventional otter board.

to 1.94 kn at a towing speed of 2 kn, practically equalizing the waterflow inside and outside the net. Furthermore, the large-mesh side panels gave good height.

This indicates that a four-seam construction method for two-boat trawls has advantages over the conventional two-seam belly and back structure.

Improved otter trawl

Based on the experiments, a new four-seam net was designed and constructed and operated with concave boards of a special design.

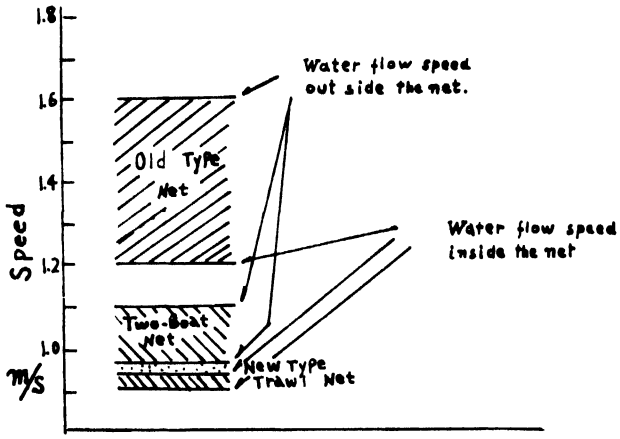


Fig. 7. Water-flow characteristics of old-type trawl, two-boat trawl and new-type net.

Otter boards—The boards were constructed with H to L ratio of 1/1.12 which had been found to give a good stabilizing effect during operation. They were equipped with flat shoes to avoid ploughing and to minimise the friction with the seabottom so that the boards would keep a more stable course in relation to the towing direction. Construction details of the new trawl boards are given in Figs 8, 9 and 10. The boards were made of steel and weighed 1200 kg in air.

Net—The net body was designed to be about six times as long as the fishing width of the net at the lower bosom, to achieve the required water release. The present net has a total length of 75.6 m (252 ft) from wing tip to

Fig. 8. New-type otter board

end of codend; the bottom net from footrope bosom to end of codend is 40 m (133 ft) and the headline is 68.33 m (228 ft). It was estimated that with 250 kg buoyancy the headline height at the wing tips would be 5 m and at the bosom 8 m. An elevator (Fig 11) was mounted on each wing tip during some of the experiments to evaluate its effect.

To achieve a smooth flow of water inside the net and

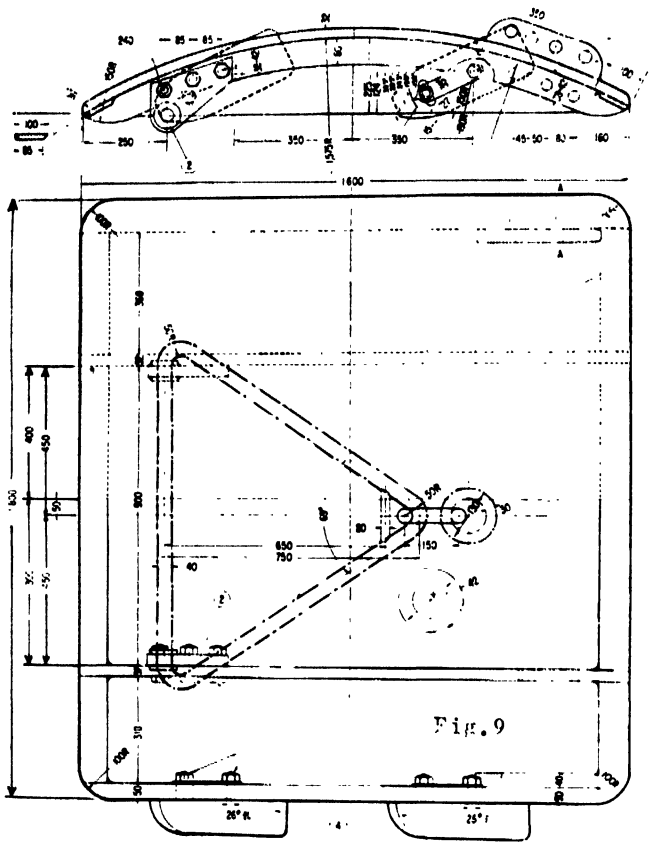


Fig. 9. Construction details of new trawl boards.

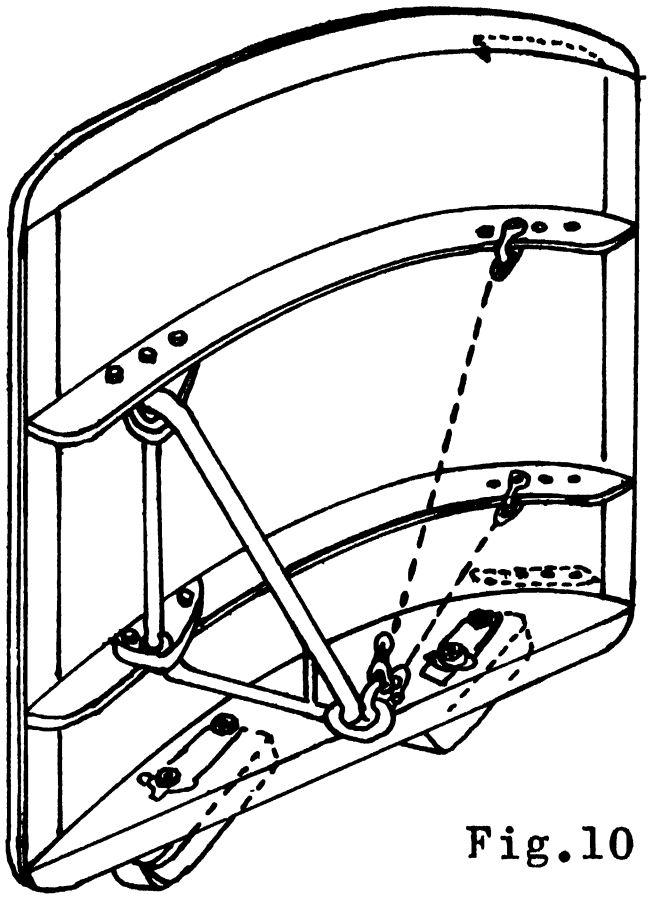


Fig. 10. Pictorial view of trawl board.

to avoid bulging, the mesh-size of the side panels was larger than that of the adjacent webbing of the top and bottom webbings, and differed by 36 mm at the opening, scaling down to 6 mm at the codend.

The whole net was made of polyethylene twine of 200 denier filaments of suitable sizes (Fig 12), to obtain lightness and lift. Except for the wing tips and selvages, all the webbing was knotless.

Assembly—The net was connected to the boards by legs of 120 m (400 ft) length, giving an estimated net opening at the wings of 26 m (87 ft), with a distance of about 70 m (233 ft) between the boards. Each leg passes through the stopper rings of strops attached to the board and during shooting it is stopped by the shackle joining the leg to the pennant (Fig 13). The upper strop is 5 m and the lower is 4 m long, giving a

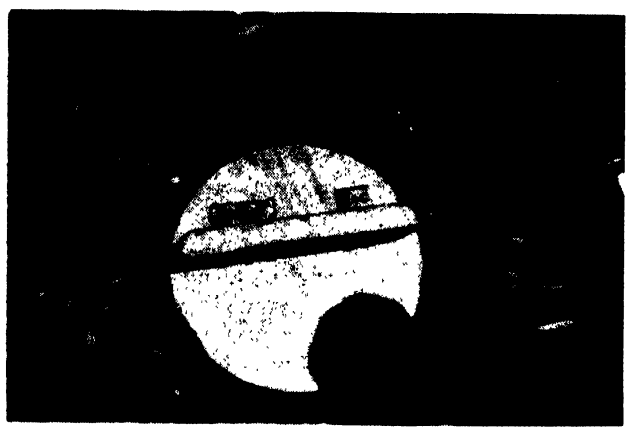


Fig. 11. Hydro-dynamic elevator.

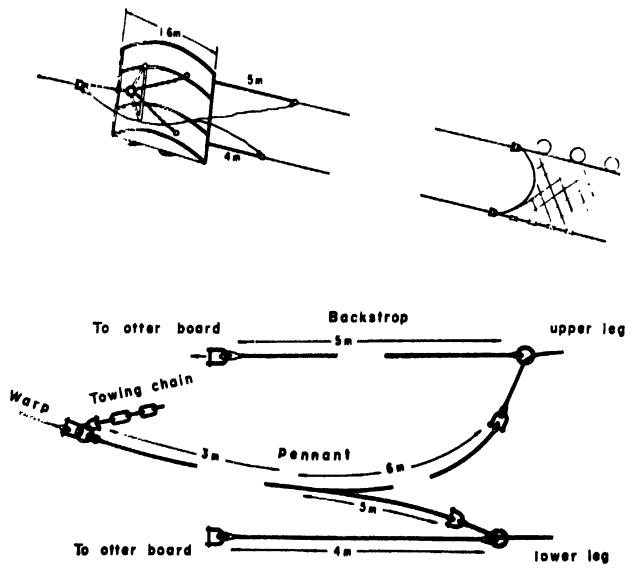
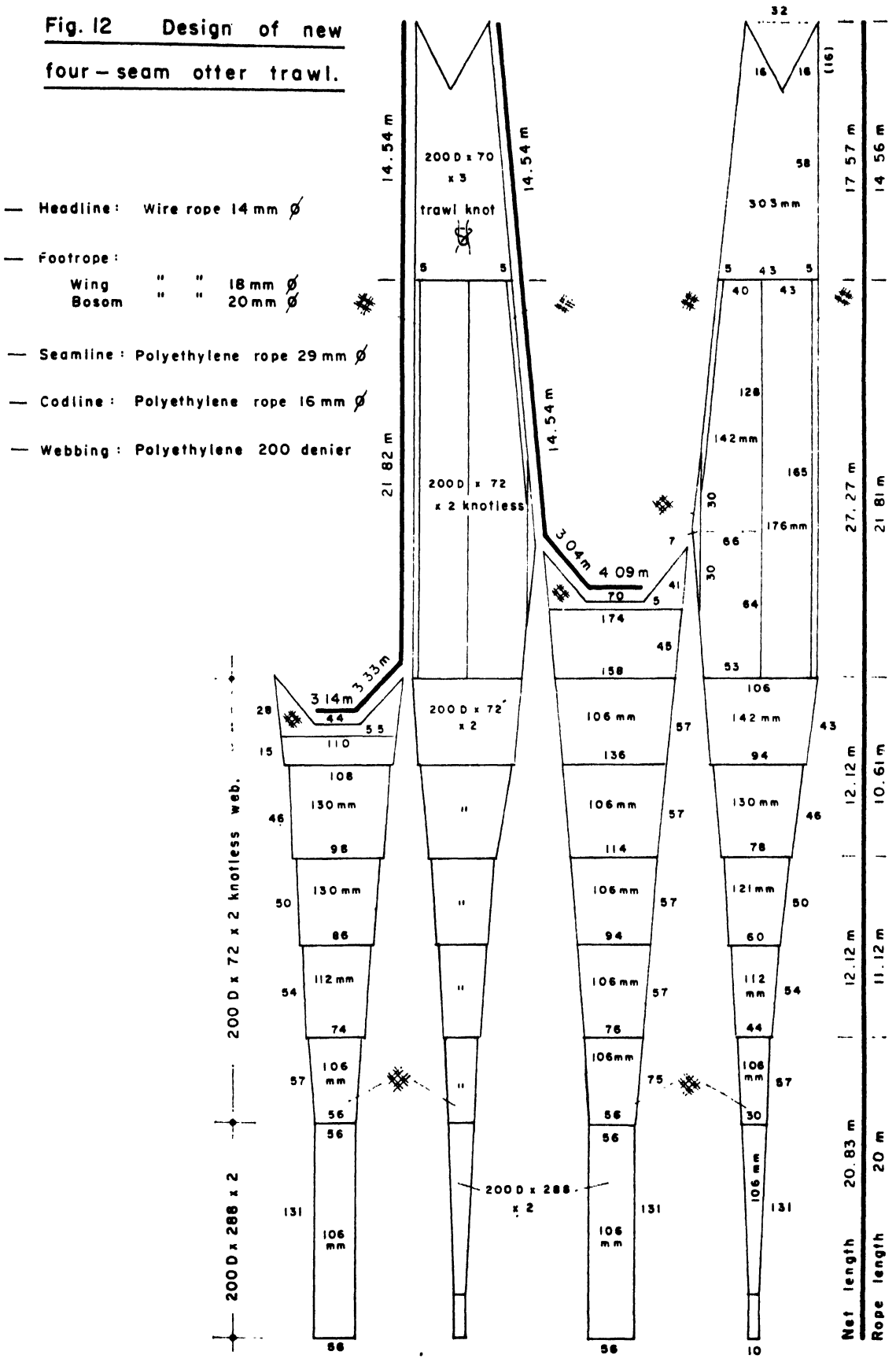
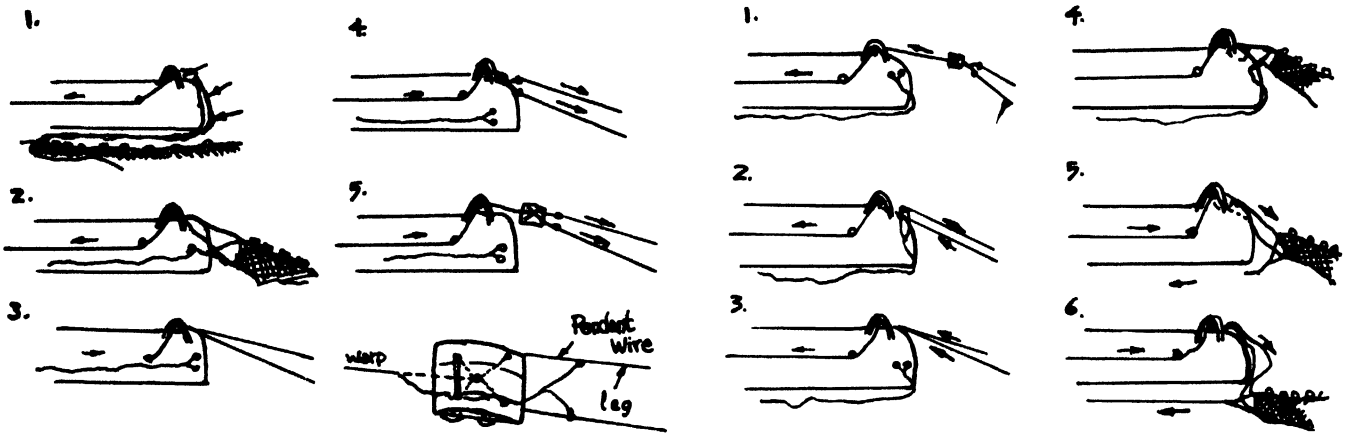


Fig. 13. Connection of net to boards.

Fig. 12 Design of new four-seam otter trawl.





Figs. 14/15. Shooting and hauling sequences.

difference of 1 m between the upper and lower connections of board and net. The shooting and hauling sequence is illustrated in Figs 14 and 15.

Experimental results—To ascertain the operational behaviour of the gear the following automatic measuring instruments were used:

recording net-height meter
„ depth meter
„ water flow meter
„ dynomometers

Both V-D and two-leg connections were used to investigate the effect on net height. During a third series, hydrodynamic elevators were attached to the wing tips. Numerical values obtained during the experiments are given in Tables I, II and III.

The horizontal net opening at the wings was calculated from the observed warp angles obtained, and was found to be slightly above 26 m, though decreasing somewhat at increased towing speeds. At this opening the side contourlines of the four-seam net make an angle of only 9° to the direction of movement, as compared to 20° for the conventional two-seam type trawl (Fig 18).

The double-leg connection gave about 2 m higher net height at the wing tips and at the bosom than the V-D connection. With the elevators, which give a lift

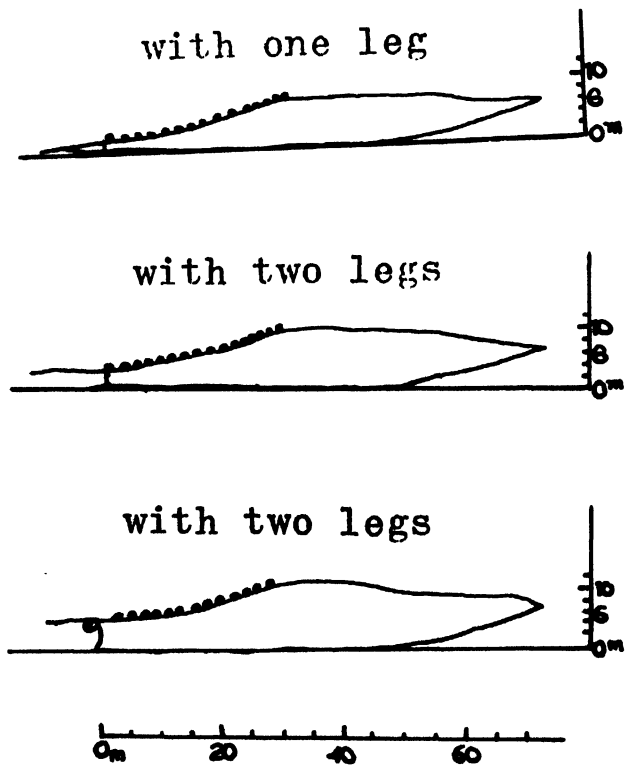


Fig. 16. Headline-height measured by recording net-height meter.

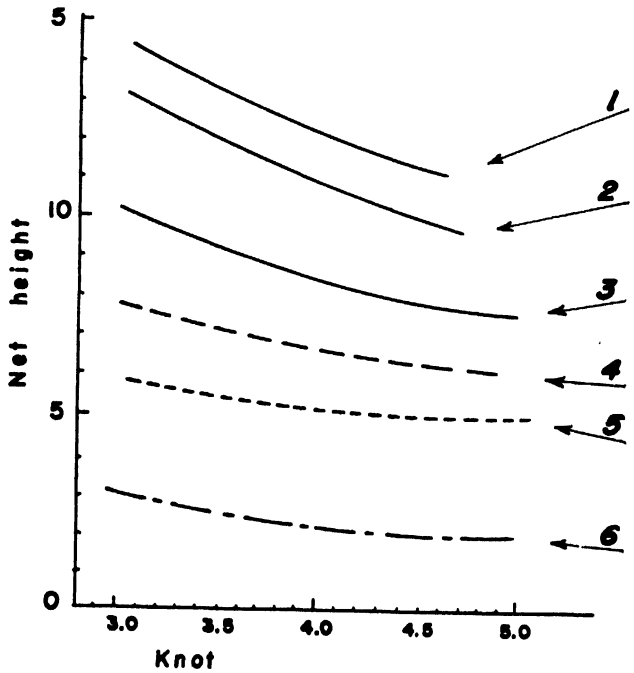


Fig. 17. Height of components of trawl nets at various towing speeds
1. Height of headline bosom (with two legs and elevator)
2. Height of headline bosom (with two legs)
3. Height of wing headline bosom (with legs)
4. Height of upper net in codend.
5. Height of wing end (with two legs and elevator)
6. Height of wing end (with single leg)

Table I. Data obtained with self-recording net-height meter, depth meter, net-against-water-speed meter, tension meter etc.

Items / Number	V-D rigged No. 1				double legs No. 2			double legs with elevators No. 3			
Items	1	2	3	4	1	2	3	1	2	3	4
Number of legs	1 leg				2 legs			2 legs			
Buoyancy of float	300 kgs				300 kgs			300 kgs			
Elevator for wing net	*	*	*	*	*	*	*	0	0	0	0
Weight of groundrope	386+90=476 kgs				386+90=476 kgs			386+90=476 kgs			
Sea depth	102 m	99	95	100	110	113	120	126	125.7	125	124
Length of warp	300 m				310 m			360 m			
Revolution per minute	150	170	190	210	190	170	200	170	190	200	190
Towing speed	3.1 kt 1.54m/s	3.6 (1.8)	4.3	4.85	3.9	3.27	4.1	3.8	4.4	4.54	4.33
Warp angle Included angle left	+ 5°	+ 6	+ 7	+4,+5	+10	+10.5	+ 8	+13	+8	+7	+6
right	+11°	+12	+10	+8,+11	+7	+ 5	+ 4	+ 3	+3.5	+2	+4
mean	8°	9	8.5	6, 8	8.5	7.7	6	8	5.7	4.5	5
Depression angle left	23	22	20	20,20	21	22	20	23	21	21	21
right	24	22	20	20,22	20	23	22	22	23	21	22
Warp tension (left)	2950kgs	3900	4300	5200	6280	—	7060	4100-4600	5900	6400-6900	5200
Height of net wing end	3 m	1.5	—	1.5	—	—	—	(6-4)	—	(5)	—
Centre of the net mouth	10 m	9	8	7.5	11.5	13	10	12	11.7	11	12
Codend	7 m	(8-7-5)	—	6	—	—	—	11	—	—	—
Water flow speed inside net	See Table II										

of about 35-40 kgs at 4.5 kn, when wing tips were raised to 5 m and the bosom to 11 m fishing height (Table II).

Table II Towing speed at 4.5 knots

Items / Number of legs	Height of forward end of wing	Height of center of bosom	Height of central codend	Reduction of flow speed inside net
1 leg	2 m	8 m	-	-
2 legs	3.5 m	10 m	-	-
2 legs with elevator for the wing	5 m	11 m	6.5 m	0.3 knots

Note:
Total buoyancy was up to 300 kgs. The floats (Polyethylene) were 24 cm in diameter, alleged to withstand water pressure of 40 kg/cm.

Table III Relative water flow inside and outside nets

Kind of net / Items	The new type net (4-seam net)	Conventional type net (2-seam net)
Outside the net	(4.33kt)(4.4kt) (4.54kt) 2.22m/s 2.26m/s 2.34m/s	(2.64kt)(3.26kt)(3.62kt) 1.35m/s 1.67m/s 1.86m/s
Inside the net	2.07m/s 2.1 m/s 2.17m/s	1.19m/s 1.18m/s 1.21m/s
Difference	0.15m/s 0.16m/s 0.17m/s	0.16m/s 0.49m/s 0.65m/s

By observation of chafing on the belly, it was found that at a distance of about 6-7 m beyond the footrope the net operated off the bottom, so that the top part of the codend operated more or less on the same height as the headline bosom. This is an important feature, especially for trawls operating on rough bottom.

Waterflow—Measurements of the waterflow inside the net, obtained during the experiments, are given in Table III where the values obtained in a conventional two-seam net are given for comparison. From the table it is clear that the difference of waterflow inside the net to the towing speed, is only 0.3 kn at a speed of 4.5 kn. Figs 19 and 20 show the recording of the waterflow in both cases.

Table IV Comparative waterflow characteristics of new four-seam net and conventional two-seam net

Kind of net / Items	New type net (4-seam net)			Conventional trawl net (2-seam net)			
				Net length 38.5m			Net length 45.5m
(1) Water flow speed outside net	4.33 2.22	4.40 2.26	4.54 2.34	2.64 1.35	3.26 1.67	3.62 knot 1.86 m/s	4.5 knot
(2) Water flow speed inside net	2.07	2.10	2.17	1.19	1.18	1.21 m/s	3.2 knot
(1) - (2) Speed reduction of the flow inside the net	0.15	0.16	0.17	0.16	0.49	0.65 m/s	1.3 knot

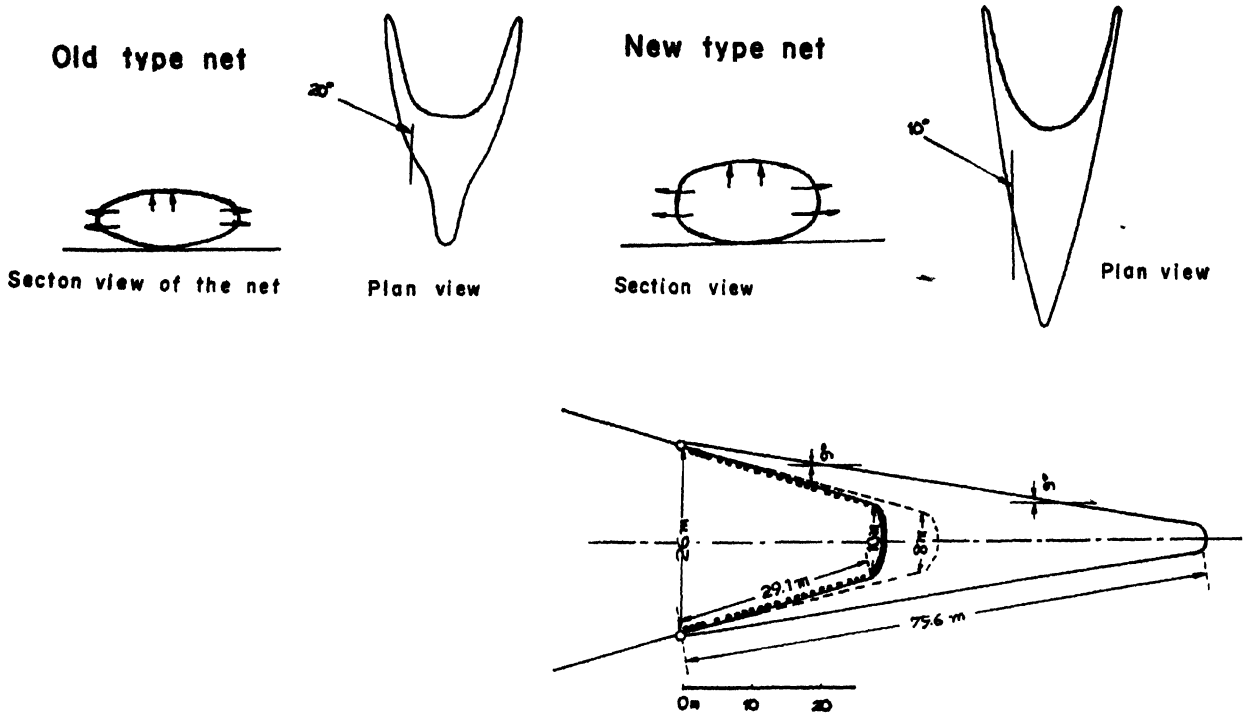
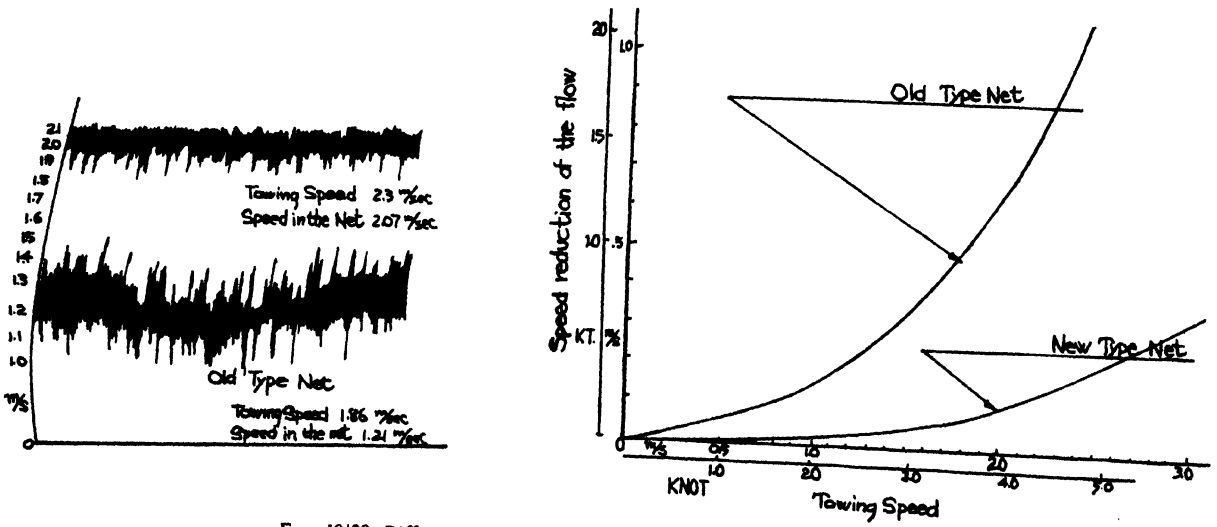


Fig. 18 Comparison of shapes of old and new-type trawl nets in operation.

Operation—Although the net was much longer than any net previously used from the *No. 50 Akebone-Maru*, no difficulties were experienced in operating the gear, either in shooting or hauling. However, measurements performed and observation of the net after hauling, indicated the importance of adjusting the warp length for the angular difference between the ship's course and the towing direction. This is especially important on stern trawlers where the distance between the stern rollers is large.

Fig 21 shows the angle made by the warps when towing with the tide on starboard. It is clear that the warp distance from the roller to the otter board is longer for the portside, and that this warp should therefore be veered out for an additional length, equal to D sin θ; where D is the distance between the stern rollers, and θ is the angle of the ship's course to the towing direction.

For the *No. 50 Akebone-Maru*, D was 11.10 m and during the experiments values as high as 1 m were found for D sin θ.



Figs. 19/20. Difference in flow speed inside and outside new and old-type nets.

Towing Power, Towing Speed and Size of Bull Trawl

Abstract
The engine power of Japanese two-boat trawlers has increased from 160 to 340 hp in the last 15 years but, due to the use of fixed blade propellers, the available engine power was not fully utilised in towing. Experiments were carried out with controllable pitch propellers and it was found that the towing power could be increased from 35 to 75 hp. In order to utilise the increased towing power, a high-opening trawl was designed and constructed and during comparable fishing operations it was found that, although the weight of the catch of the new gear was of the same order as that of the traditional gear, the fish were generally of a larger size and better value.

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Puissance, vitesse de touage et dimensions du chalut a deux bateaux

Résumé
La puissance des machines des chalutiers à deux bateaux Japonais a augmenté au cours des 15 dernières années et est passée de 160 à 340 c.v. mais étant donné qu'ils employaient des hélices à pas fixe, cette puissance n'était pas utilisée pleinement dans le chalutage. Des expériences ont été conduites avec des hélices à pas variable et on a trouvé que la puissance de touage pouvait ainsi passer de 35 à 75 c.v. Pour profiter pleinement de cette force de touage supplémentaire, un chalut à grande ouverture a été dessiné et construit et pendant des opérations de pêche comparatives, on a constaté que les captures effectuées avec le nouveau chalut étaient égales poids à celles effectuées avec le chalut traditionnel, mais que les poissons capturés étaient généralement plus grands et d'une valeur supérieure.

Fuerza y velocidad de remolque y dimensiones del arte

Extracto
La potencia de los motores de las parejas Japonesas ha aumentado de 160 a 340 hp en los últimos 15 años, pero por causa del empleo de hélice de palas fijas la fuerza disponible no se ha aprovechado por completo en el remolque. Se realizaron experimentos con propulsores de paso controlable y se demostró que la potencia de remolque podía aumentarse de 35 a 75 h.p. Para aprovechar plenamente la mayor fuerza de remolque se proyectó y construyó un arte de mucha abertura en altura y durante actividades de pesca comparativa se demostró que aunque la captura total del material modificado era del mismo peso que la del tradicional, el pescado era en general de mayor tamaño y más valioso.

THE engine power of the two-boat trawlers in Japan has increased from 160 to 340 hp in the last 15 years. The main object was to obtain higher speed to minimise the time spent in steaming from port to the fishing grounds and back, as well as to speed up the move from one fishing ground to another.

Due to the use of fixed-blade propellers, the available towing power did not increase proportionally to the increase in engine power so that the fishing gear has remained almost unchanged.

The Fishing Boat Laboratory tested a pitch propeller which increased the effective controllable propeller power while trawling from 35 hp to 75 hp.

Vessel and propeller

The vessels used during the experiments were the *No. 23* and *25 Yamada Maru*, both having 98 tons displacement with diesels of 340 hp at 385 r.p.m. Manganese bronze controllable-pitch propellers were used, three-blade, 1,600 mm diameter, 7,500 cm² developed area.

Continued from page 198

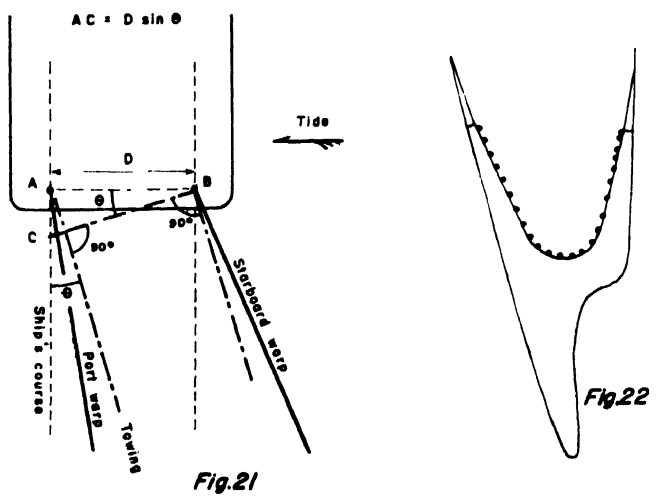

Fig. 21. Difference (A-C) in warp length from roller to otterboards when towing with tide on starboard.

Fig. 22. Net distorted when towing with tide on starboard.

When towed with equal lengths of warp in the above case, the weatherside wing was found to contain seaweed stuck in the meshes while practically none was apparent in the leeside wing. This pointed to a distorted net during towing, as illustrated in Fig 22. During subsequent hauls, the lee warp was lengthened by the amount D sin θ according to the drift angle, and seaweed then got caught equally in both wings. The angle θ changes as the drift changes and is not constant throughout the haul. One way of avoiding constant changes in warp length on stern trawlers would be to centre the top rollers (towing blocks) at a point from where the warps are paid out. However, this would adversely affect the opening width of the net.

The above trawl gear is now being used in commercial fishing by big stern trawlers in the Bering Sea and the Atlantic, and also by medium-size trawlers in the East China Sea, and is giving 150 to 200 per cent better results than the conventionally used trawls.

Such propellers are normally for vessels of the *Yamada Maru* class.

Summary of the experiments

The vessels were connected stern to stern with a 200 m long manila hawser. Towing was done of varying degrees of pitch and r.p.m. of the propeller (Fig. 1).

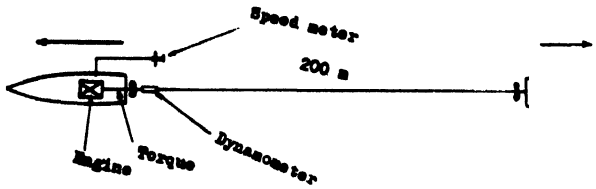

Fig. 1. Operational method during towing tests.

The towed vessel kept a constant pitch on the propeller but changed the propeller revolutions to allow the towing vessel to attain the various speeds required for obtaining the necessary data. The instruments included specially constructed dynamometers of 2·5 to 5 tons, special logs designed and constructed at the Fishing Boat Laboratory, and strain gauges for accurate measuring of the propeller shaft torque.

The measurements taken included:

(a) Warp tension (pull).
(b) The vessel's speed.
(c) The torque of the propeller's shaft.
(d) The exhaust gas temperature of the main engine.
(e) The mean pressure for each cylinder.
(f) The fuel consumption.

All instruments were installed on the towing vessel which issued instructions as to speed, etc., to the towed vessel. The relations were defined between propeller pitch, propeller speed, fuel consumption, torque and ship's speed.

Result of the towing tests

The results are summarised in Fig. 2. The results calculated for towing speeds of $2\frac{1}{2}$ to $3\frac{1}{2}$ knots are also shown in Fig. 3 in another way. The maximum towing pull normally utilised was extracted from the data provided in the graph and was taken for the following conditions:

(a) For a maximum exhaust temperature of the main cylinder during operations of 350°C.
(b) For a maximum mean pressure of the main cylinder of 5·2 kg/cm².
(c) For a minimum fuel consumption.

The towing power under the above conditions was measured and the results are given in Table I.

TABLE I.

Speed	Tension (pull)	Pitch	Revolutions	S.H.P.
2·5 knots	3·5 tons	13·5°	353 r.p.m.	262 P.S.
3·0 knots	3·4 tons	13·8°	,,	,,
3·5 knots	3·3 tons	14·2°	,,	,,

Design of the trawl gear

The normal power on two-boat trawlers is 320 to 340 hp and most vessels have fixed pitch propellers. As the pitch has normally been selected for free running, power available for towing is therefore relatively small. Tests have shown that at 2·3 knots the pull is about two tons; this means that towing power is around 35 hp. By

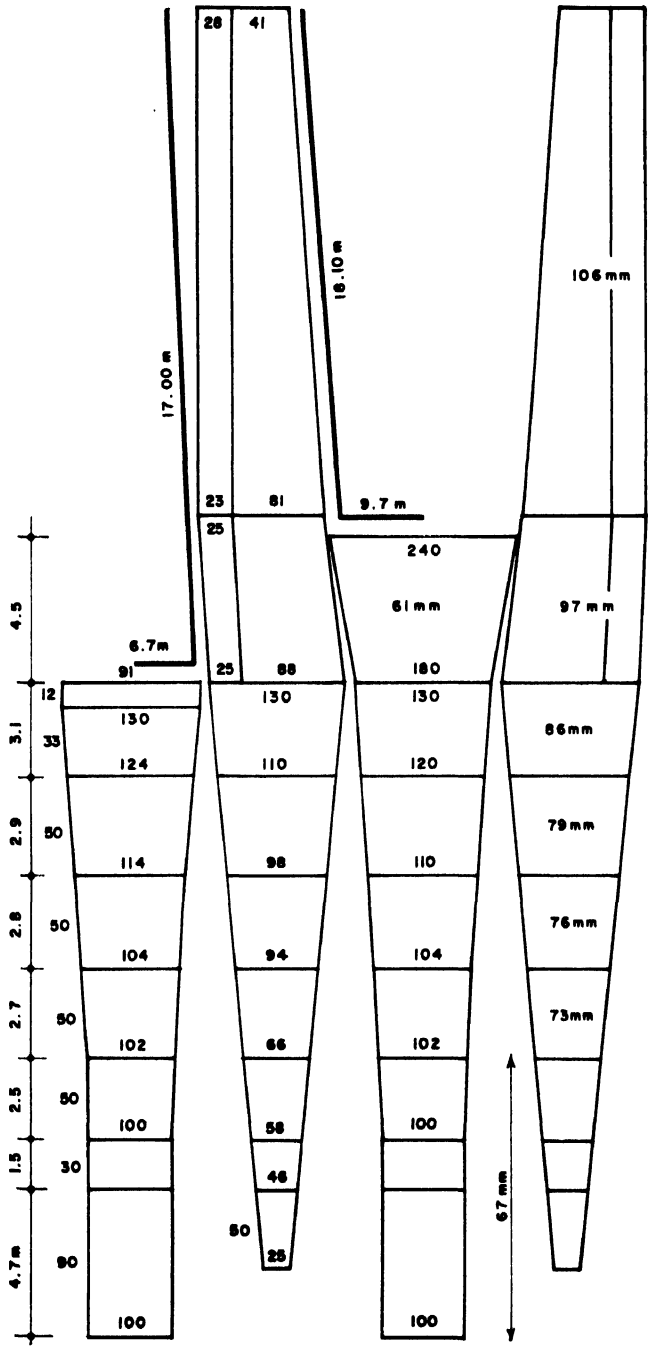

Fig. 4. Traditional manila two-boat trawl.

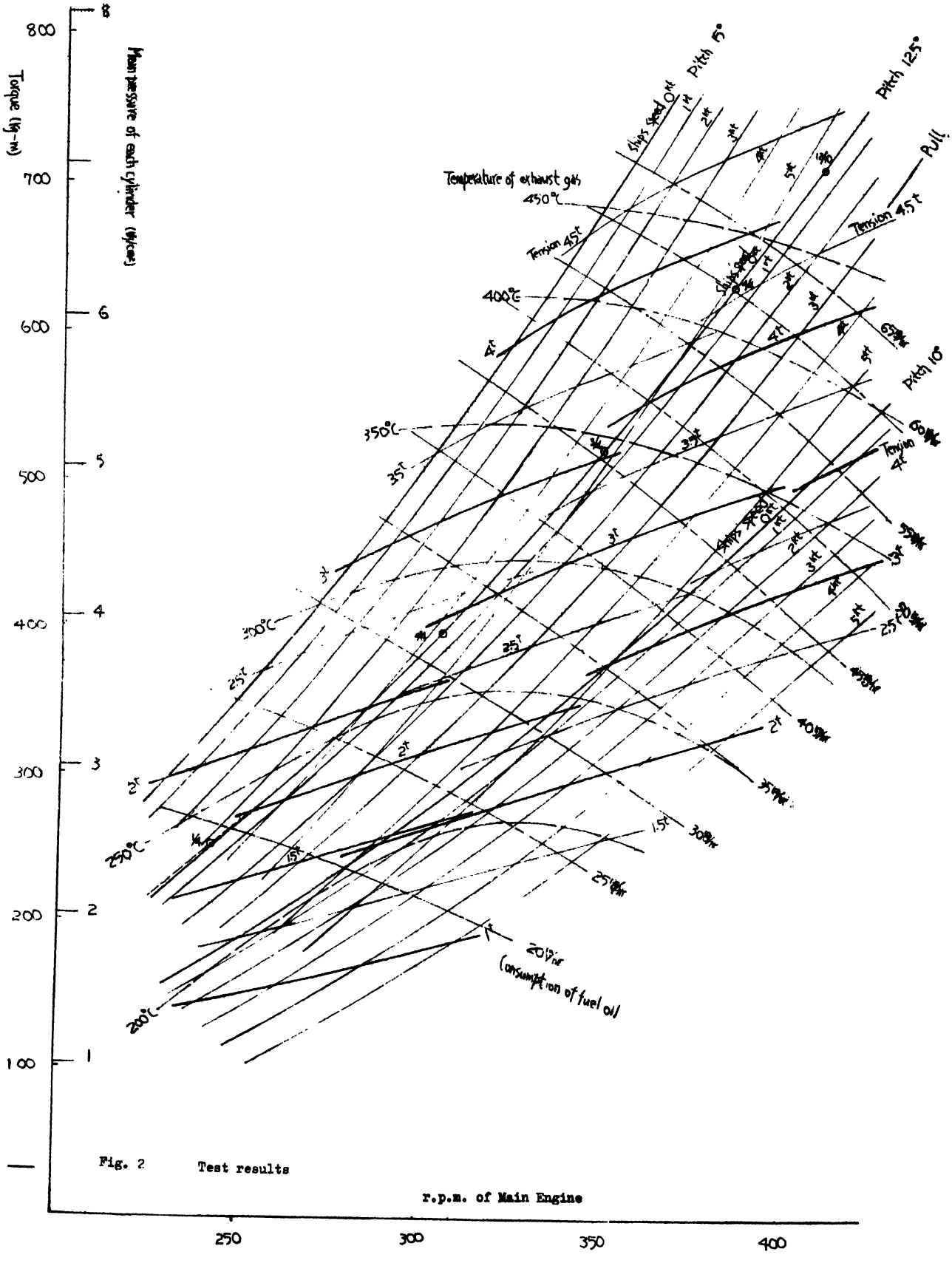

Fig. 2 Test results

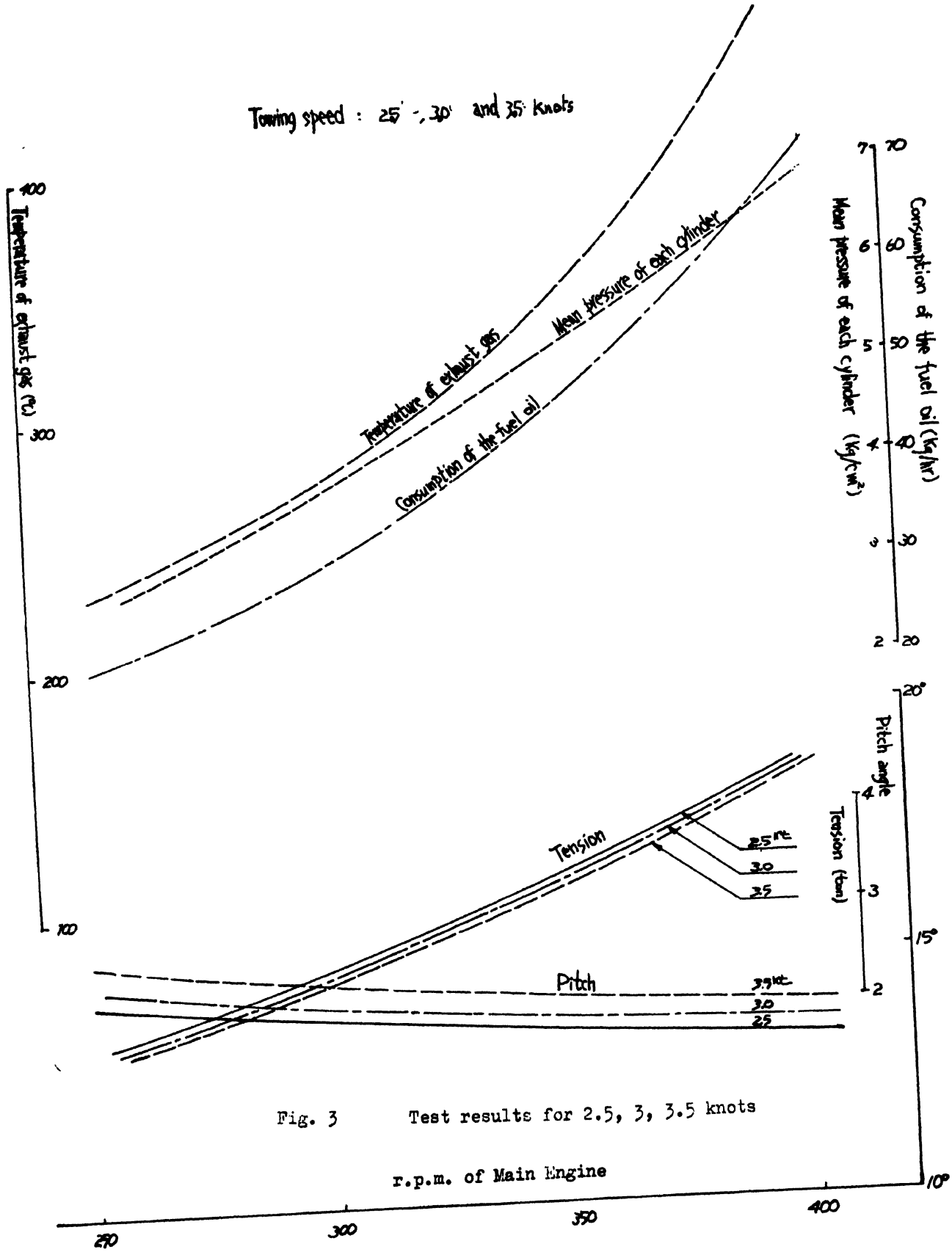

Fig. 3 Test results for 2.5, 3, 3.5 knots

using a controllable-pitch propeller, the towing power was increased to 75 hp.

Fig. 4 gives the design of the traditional type of two-boat trawl. A new type of trawl was designed to have a minimum of resistance during towing at high speeds. The headline height was found to be about 5 m at $3\frac{1}{2}$ knots. Construction details are given in Fig. 5. An elevator, Fig. 6, is attached at each wing for assisting the wing to reach its maximum height.

Measurements were taken of warp tension and headline height; these, together with the data previously given, are shown in Table II.

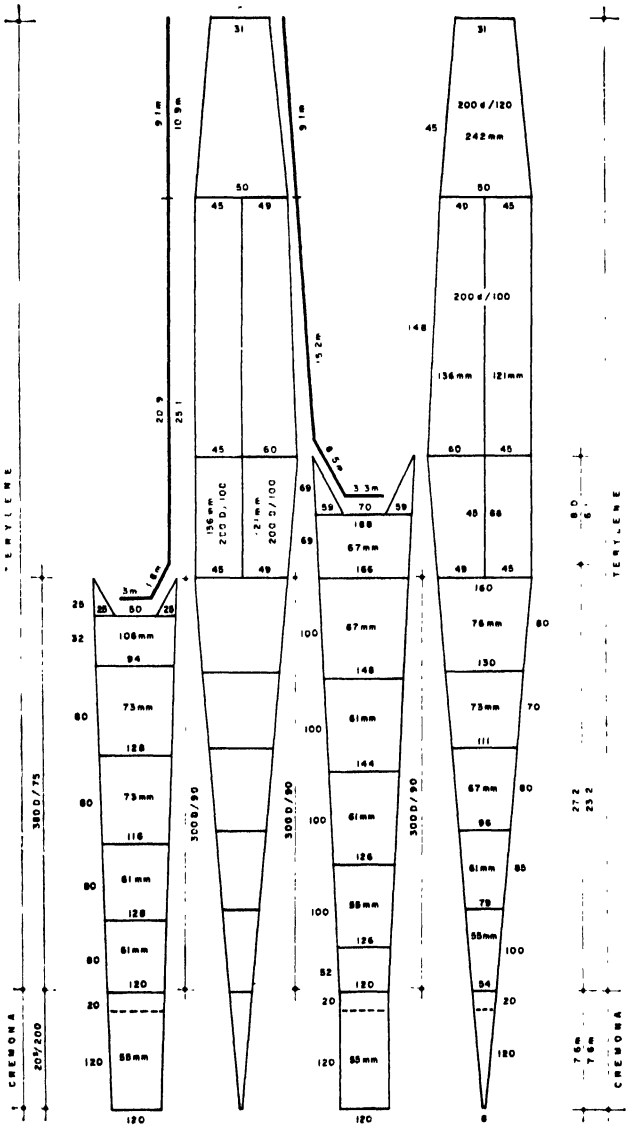

Fig. 5. Design of improved two-boat trawl.

Table II.

	Towing Speed	
	2·8 knots	3·5 knots
Propeller pitch	13°	14°
Propeller r.p.m.	300	340
Temperature of the exhaust	245°C	320°C
Mean pressure	3·3 kg/cm²	4·7 kg/cm²
Consumption of fuel	27·5 kg/hr	49·0 kg/hr
Distance between the boats	245 m	230 m
Warp tension	2·2 tons	2·8 tons
Net height	4·9 m	4·5 m

Result of fishing operations

Experimental fishing was carried out on the normal fishing grounds in the Yellow Sea during the beginning of September, 1962.

The new gear and the traditional gear were towed alternately by a pair of trawlers. The catches of large- and middle-sized yellow croaker were 150 per cent higher than with the traditional trawl; the catches of small fish and bottom species were, however, less. The total weight of the catch was approximately the same but, the market price for the bigger fish was higher.

This new net has been designed for high opening and high-speed towing. If the fish population is composed mainly of bottom fish, the design of the net should be altered to obtain a wider opening at the cost of a lower height, conserving the high-speed feature of the trawl. In any case, any new design must incorporate total use of the full thrust available from the engine—having a controllable-pitch blade propeller.

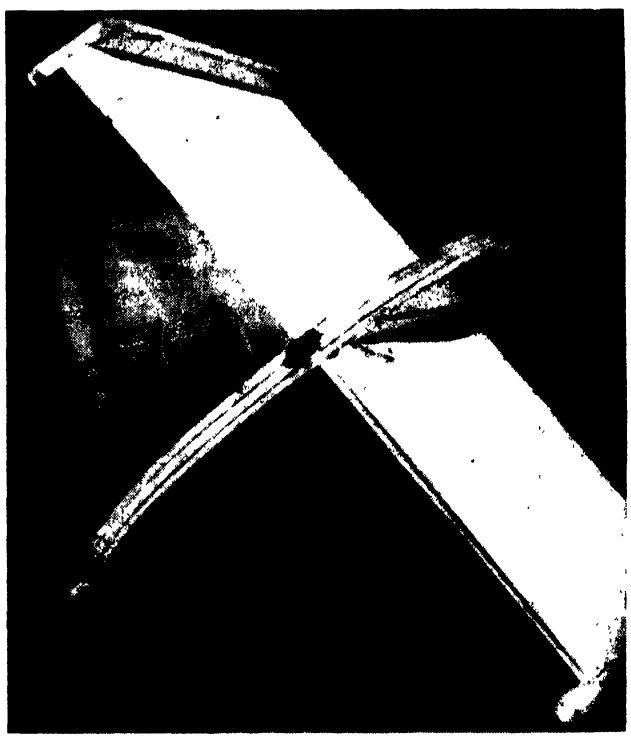

Fig. 6. Elevator used during experiments.

Suggestions for Improved Heavy Trawl Gear

Abstract
The author who is an outsider to the fishing industry, presents his general suggestions for the improvement of heavy bottom trawl gear as a stimulus for fisheries experts to work out practical solutions to the advantage of both the trawling industry and the submarine cable companies. His proposed modifications aim at decreasing the towing resistance and the risk of fouling the gear on obstacles on the bottom. The main suggestions are: To modify the bracket or bridle arrangement of the otter boards to fend off objects which otherwise would be hooked or, even better, to operate the otter boards off the bottom, attaching them directly to the leadline, and by using a different rig and different designs and/or other materials (light plastic) for the boards; also to eliminate bottom-touching sweeplines. To enhance catching efficiency, sound or electricity should be utilised to guide the fish towards the net opening. To carry out such gear development projects efficiently and quickly, the establishment of integrated "systems development" teams on national, or even international, scale is suggested rather than widely scattered individuals or small groups working without co-ordination. If the design objectives include the avoidance of damage to submarine cables, the international communications firms might be willing to assist.

Suggestions pour modifier le chalut lourd

Résumé
L'auteur qui n'est pas un spécialiste dans l'industrie des pêches, soumet dans cette étude certaines idées pour l'amélioration des chaluts lourds de fond, pour lesquels les experts en matière de pêche pourront peut-être trouver des solutions pratiques intéressantes pour l'industrie des pêches et les compagnies de câbles téléphoniques sous-marins. Les modifications proposées tendent à réduire la résistance de l'engin et les risques d'accrochage aux obstacles du fond. Ces suggestions comprennent la modification des brides ou arrangement d'une chaîne sur les panneaux de telle sorte qu'il ne soit pas possible d'attraper des objets avec le panneau ou mieux, d'opérer de telle façon que les panneaux soient au-dessus du fond en les attachant directement à la ligne de fond ou encore par la modification du dessin de l'engin et en utilisant pour les panneaux, les nouvelles matières comme le plastique, surtout pour empêcher que les bras ne traînent sur le fond. Pour améliorer la capture, pleine utilisation devra être faite du son et de l'électricité pour guider les poissons vers l'ouverture de l'engin. Pour l'exécution rapide et efficace de ces projets, des "systèmes de développement" établis par des équipes nationales ou internationales seront certainement plus efficients que des efforts individuels ou de petits groups travaillant sans coordination. Les compagnies internationales de communications sont prêtes à aider à la réalisation de ces projets si les travaux permettent en même temps d'eviter les dommages causés aux câbles sous-marins.

Sugerencias para mejorar artes de arrastre pesados

Extracto
El autor, que es ajeno a la industria pesquera, hace sugerencias generales para mejorar los pesados artes de arrastre de fondo con objeto de estimular a los especialistas pesqueros a encontrar soluciones prácticas que redunden en beneficio de la industria de la pesca al arrastre y de las compañías explotadoras de cables telegráficos submarinos. Propone, en sus modificaciones, reducir la resistencia al remolque y el riesgo de que el arte se enganche en obstáculos del fondo. Las principales sugerencias son: modificar el brazo o el enganche del pie de gallo de las puertas para evitar obstáculos en los que podrían engancharse o, lo que sería todavía mejor, separar las puertas del fondo sujetándolas directamente a la relinga de plomos, emplear diversos herrajes, formas o materiales (plásticos ligeros) y eliminar las malletas que tocan el fondo. Para incrementar el rendimiento de pesca deberían emplearse sonidos o corrientes eléctricas que guíen a los peces hacia la abertura del arte. Con objeto de que estos proyectos puedan llevarse a la práctica rápida y eficazmente, convendría crear grupos de "estudios de sistemas" en escala nacional o internacional, en vez de tener individuos o grupos pequenos aislados que trabajan sin coordinación. Si una de las finalidades del proyecto es evitar causar averías a los cables submarinos, las empresas internacionales que los explotan es posible que estén dispuestas a ayudar.

by
Eldon Nichols

Cables Division, American Telephone & Telegraph Co.

WHY has heavy trawling gear been improved so little in recent years? Important advances have been made in the design of large trawlers and in techniques for handling and processing the catch but trawling gear has undergone only minor refinements. The present trawl works quite well on relatively smooth bottom at moderate depths (the conditions for which it was designed) but today much trawling is done on uneven and rough bottom at depths ranging to more than 300 fm. Under these conditions, hang-ups and fouling are common and the width and height of the mouth vary erratically as the otter boards lurch and heave. Drag is excessive, limiting the size of the net and the trawling speed and increasing fuel consumption.

This situation came to attention during studies of the causes of damage to submarine cables and some consideration was given to it. The results are presented here with the hope that a look at the subject from an outsider's point of view may provoke interest among fisheries people and lead to effective action.

Need for basic changes

Till now most changes have involved only replacements and adjustments in one or two specific components, e.g., the substitution of heavy bobbins for rollers, and not all have been very beneficial. In fact, matters are often made worse by attaching weights to doors and reducing scope to shorten the hauling-in time. This increases the heaving of doors by sea and swell.

It seems clear that the design of a fundamentally new trawl is indicated, rather than the mere substitution of new otter boards, floats, or other items. Although substantial development work will be required to determine details of a new trawl, it may be useful to suggest a general line of approach.

Preview of a new trawl

First, the basic geometry of the trawl needs investigation. In the present structure the vertical component of the towing force acting on the warps is opposed and wasted by the weight and tilt of the otter boards. If the warps were attached to the headline, they would lift it, eliminating, or at least reducing, the need for floats. With fewer or smaller floats there would be less drag on the headline.

This would permit the use of smaller otter boards which would give further reduction in drag.

These changes would eliminate the groundrope legs and this should reduce hang-ups to less than a third of the present number. It may be objected that the otter boards must be separated from the wings by legs or sweeplines in order to scare fish into the net. This theory seems to be questionable when trawling is done in deep and turbid water, at high latitudes, or at night. Under these conditions the light is undoubtedly too dim for the otter boards and lines to be visible for more than a few feet. And if sound or pressure waves, rather than light, is thought to be the agent that scares the fish, a more efficient frightening or guiding device than the present otter boards and sweeplines could surely be designed. In recent experiments in the U.S.A., increases in catches were obtained by passing electric currents through the water near the mouth of the net. This appears to be a much more promising method than the use of sound.

Improvement in the method of attachment is particularly important. The forward end of the present type of otter board, together with the bracket and the warp, form a hook that will foul almost any object in its path. This hook can be eliminated by the use of a bridle or bracket attached to the top and bottom corners of the leading edge of the door in such a way as to fend off objects encountered. This, of course, is only a refinement of the chain bridle, long in use in small trawls. This change would interfere with the use of the "G" link, Kelly's eye and stopper for the quick disconnection of the otter boards when hauling in. However, with the otter boards attached directly to the ends of the headline, as will be the case with the groundrope sweeplines eliminated, disconnection would not be necessary.

It is also proposed that the otter boards be removed from the bottom and made "free swimming". This would do away with the extreme variations in spreading force which now occur due to the shoe intermittently scraping up ridges of sediment and jumping over them. Also eliminated would be the variations in spreading force, due to the sudden changes in effective aspect ratio whenever the otter board leaves the bottom or returns to it.

The new otter board should have a little positive buoyancy which in the past has been unattainable due to the quick waterlogging of the wooden planks under pressure. Now it is feasible to make strong, light hydrofoils of a rigid plastic foam, such as polyurethane, covered with fibreglass. The very smooth surface, free from iron braces and bolts, should give a substantial increase in lift-drag ratio. The foamed plastic core should be either tapered in density from top to bottom, or slightly weighted at the bottom, to make it seek a vertical position in the water. This will correct the tendency of the present otter boards to fall flat when launched, when veering or when the warp goes slack for any reason, such as the heaving of the trawler in the sea.

Second, ways should be found to make better use of synthetic fibres in nets. Fishermen have been understandably reluctant to make full use of them due to their higher cost and to practical difficulties in tying them. But if these faults can be overcome, their low friction, light weight and high strength should pay dividends in reduced drag and maintenance.

Third, new inventions and ideas should be reviewed to see if they fit into the general framework of trawl gear improvement, or if any of them are important enough to warrant a change in this framework; e.g., a new headline float intended to give more lift with less drag would be examined as a possible replacement for the current types. On the other hand, an invention such as the recent Canadian one, in which a hydrofoil equipped with a hydrostatic control always seeks a preset depth, would be considered as a possible way to eliminate headline floats.

Further study may show that some of the design features just proposed are not practical but the point is that trawls of novel design are possible, that there are new ideas and materials waiting to be put to work and that little is being done about this situation, although even a minor improvement involving so many trawlers would have substantial value.

Organising for development

If it is agreed that the development of a better deep-water trawl is possible and desirable, the next question is: How can it be accomplished? Much of the rapid technological progress in modern industry is due to the employment of integrated "systems development" teams capable of carrying projects all the way through to commercial operation, rather than widely scattered individuals or small groups working without co-ordination. Fisheries people must find ways to employ this powerful method.

A development team capable of handling the project under discussion should include high-grade fishing gear technologists, expert designers and makers of nets and gear, outstanding trawler officers and an able and experienced leader. Also, there should be arrangements for occasional consultation with specialists in such fields as hydrodynamics, marine biology, plastics and electronics.

In any of several countries, such a team could be assembled from the competent people now engaged in fisheries work. A board with members drawn from the government fisheries department, universities and manufacturing and fisheries companies could establish policies, select the key members of the team and provide general co-ordination. The funds required to finance the undertaking might be contributed jointly by the companies and the government. They should not be much larger than those now being spent by the several organisations working separately but the results could be much more valuable.

Another attractive possibility is the formation of a joint enterprise in which several countries would co-operate, perhaps under FAO leadership. In this case, the financial contribution from each party would surely be within reach.

Development of Soviet Trawling Techniques

Abstract
Soviet development is toward active high-sea fisheries. The principal gear is the bottom trawl. Five stages of its development since 1878 are shown in sketches. Most modern trawling is done at 150 to 250 m, at speeds up to 3·5-5·0 knots for periods of 1½ to 3 hours, with bottom gear of these general specifications: 60 m long; 25 to 40 m horizontal opening; up to 3 m vertical opening. The *Novator* in 1948, followed by the *Pushkin*-class vessels, led to the modern 1,900 hp sterntrawler with completely mechanised processing facilities. Continuing experience dictates changes such as smaller vertical opening of the net for plaice; larger vertical opening and greater speed for herring; and variations in vertical and horizontal opening for cod and haddock. Soviet trawlers use oval, slotted otter boards which are more durable, lighter and have 19 per cent more spreading force than ordinary otter boards of comparable size. Midwater trawling was first tried in the 1920's but is still in the developmental stage. North Atlantic midwater trawling has occasionally produced more than 20 tons in 30 minutes' trawling. A scheme of controlling the net-filling rate is diagrammed. A transmitter enclosed in a ball attached to the headline is connected with a transducer installed in the codend; the transmitter sends signals to a receiver in the wheelhouse. Only some gear parameters can be studied with present methods and instruments. The author diagrams what he believes is the most advanced installation for gear trials. In this, two endless steel ropes are attached to a pontoon mounted on two floats. The gear to be tested is secured to the ropes; the pontoon serves as a platform for cameras, lights and other instruments to register changes in parameters as the gear is towed at various speeds across a natural basin which has no current and is sheltered from the wind. The method permits testing full-scale gear and one-half and quarter-scale models. The author describes another special instrument, an under-water dynamograph which can continuously record, for 90 minutes, the stresses in rope and wire to 350 m depth. Another instrument is sketched which records the net's vertical opening by means of an expandable tank transmitting pressure variations through a liquid-filled hose to a recorder. Fish behaviour and gear catchability studies use the usual aqualungs, bathyscopes and under-water equipment but, in addition, the special submarine *Severyanka* permits long-term observations and photography.

by
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Développement des techniques de chalutage soviétique

Résumé
Le développement de la pêche soviétique est axé sur la pêche hauturière. L'engin principal est le chalut de fond. Les cinq stades de développement depuis 1878 sont racontés par des illustrations. Le chalutage moderne est généralement pratiqué de 150 à 250 m de profondeur, à des vitesses de touage allant jusqu'à 4·5 noeuds, par périodes de 1½ à 2 heures, avec des chaluts de fond ayant les caractéristiques suivantes: 60 m de long, 25 à 40 m d'ouverture horizontale et jusqu'à 3 m d'ouverture verticale. Le *Novateur* en 1948, puis les chalutiers de la classe *Pouchkine* ont conduit aux chalutiers à pêche arrière modernes de 1900 c.v., entièrement mécanisés avec possibilité de traiter le poisson. En prolongeant l'expérience, il est apparu que certaines transformations devaient être introduites, à savoir: ouverture verticale moins grande pour les chaluts à plies, ouverture verticale plus grande et vitesse accélérée pour les harengs, variations dans l'ouverture verticale et horizontale pour le cabillaud et l'églefin. Les chalutiers soviétiques utilisent des panneaux ovales, munis de fentes, qui sont plus résistants, plus légers et ont une force latérale supérieure de 19 pour cent à celle des panneaux ordinaires de dimensions comparables. Le chalutage, pélagique fut commencé en 1920 mais est encore à un stade de développement. Dans l'Atlantique du Nord il a parfois produit des captures de plus de 20 tonnes pour une demi-heure de chalutage. Un diagramme représente un système de contrôle de la vitesse de remplissage du chalut. Un émetteur placé dans un globe est attaché aux ralingues supérieures et relié à un radio-émetteur installé sur le sac; les échos reçus du sac sont transmis à un récepteur situé dans la timonerie. Les paramètres des engins de pêche pouvant être étudiés par la présente méthode sont limités. Des diagrammes de l'installation que l'auteur suppose être la plus avancée pour faire des épreuves d'engins de pêche, sont donnés dans la communication. Cette installation comprend deux cordes d'acier continues, attachées à un ponton monté sur deux flotteurs; les cordes passent par l'engin à éprouver; le ponton porte les caméras, lampes et autres instruments pour enregistrer les changements des paramètres de l'engin qui est toué à des vitesses différentes, dans un bassin naturel n'ayant pas de courant et à l'abri du vent. La méthode a permis de faire des essais à l'échelle du modèle, et à des échelles réduites de moitié et du quart. La communication décrit un autre instrument spécial, un dynamographe sous-marin, qui peut enregistrer continuellement pendant 90 minutes les tensions exercées sur les cordes jusqu'à une profondeur de 350 m. Un autre instrument enregistre l'ouverture verticale du filet au moyen d'un réservoir sensible à la pression qui transmet à l'enregistreur les variations de pression par l'intermédiaire d'un tube plein d'un liquide. Pour les études du comportement du poisson et de l'efficacité de capture des engins, des bouteilles d'oxygène, des bathyscaphes et tout un équipement sous-marin ont été utilisés normalement, mais en plus, le sous-marin spécial *Severyanka* a permis de faire des observations de longue durée et des photographies.

Evolución de las tecnicas soviéticas de pesca al arrastre

Extracto
Las actividades soviéticas se encaminan hacia la pesca de gran altura empleando principalmente el arte de arrastre de fondo. El autor da ilustraciones de cinco fases de su evolución desde 1878. Actualmente la pesca al arrastre se practica en fondos de 150 a 250 m, a velocidades hasta de 4·5 nudos por períodos de 1·5 a 3 hrs, con artes de las siguientes características generales: longitud, 60 m; abertura horizontal de 25 a 40 m y vertical hasta de 3 m. El *Novator* en 1948 y posteriormente los barcos de la clase *Pushkin* han culminado en el modernísimo arrastrero con rampa a popa con motor de 1,900 hp y manipulación y elaboración completamente mecanizadas. La experiencia aconseja el empleo de redes de abertura en altura pequeña para la pesca de peces planos; de mayor abertura en altura y velocidad para el arenque; y variaciones en las aberturas horizontal y en altura para bacalao y

Continued from page 205

If the design objectives include the avoidance of damage to submarine cables, there is good reason to expect that the international communications interests will be willing to assist.

Only a single, specific development programme has been discussed here. If it is carried through successfully there should be strong incentive to retain the organisational framework and to take up other problems. In many industries the most healthy and prosperous companies are those which allocate a significant part of their budgets to research and development. Can trawler owners afford not to follow this example.

eglefino. Los arrastreros soviéticos emplean puertas ovaladas, con ranuras, que duran más, son más ligeras y tienen un 19 por ciento más de fuerza de abertura que las normales de dimensiones análogas. La pesca entre dos aguas se practicó por primera vez en la tercera década de este siglo, pero está todavía en la fase experimental. Esta pesca, practicada en el Atlántico septentrional, ha producido en ocasiones más de 20 tons de pescado en lances de 30 min de duración. Se da un esquema del proyecto para regular la velocidad a que se llena la red. Un transmisor metido en una esfera ligada a la relinga de corchos está conectado con un transductor instalado en el saco; el transmisor envía senales a un receptor instalado en la caseta del timón. Con los métodos e instrumentos actuales sólo se pueden estudiar algunos parámetros de los artes. El autor da esquemas de lo que es a su juicio la instalación más avanzada para ensayar artes. En ésta, dos cables de acero sinfín se sujetan a un pontón montado en dos flotadores; el arte que se va a ensayar se ata a los cables; el pontón sirve como plataforma para cámaras, luces y otros instrumentos que registran los cambios en los parámetros cuando el arte se remolca a diversas velocidades por un estanque natural en el que no hay corrientes y está protegido del viento. Este método permite ensayar modelos a la mitad y un cuarto de la escala total. El autor describe otro instrumento especial, un dinamógrafo submarino que registra continuamente durante 90 min los esfuerzos a que están sometidos los cables de fibra y de acero a profundidades de 350 m. Da un esquema de otro instrumento que registra la abertura en altura de la red por medio de un dispositivio de expansión que, a través de una manguera llena de liquido, transmite las variaciones de la presión a un registrador. El comportamiento de los peces y la capacidad de pesca de los artes se estudian por buzos autónomos, batiscafos y equipos submarinos, así como con el submarino especial *Severyanka* que permite hacer observaciones y tomar fotografías durante mucho tiempo.

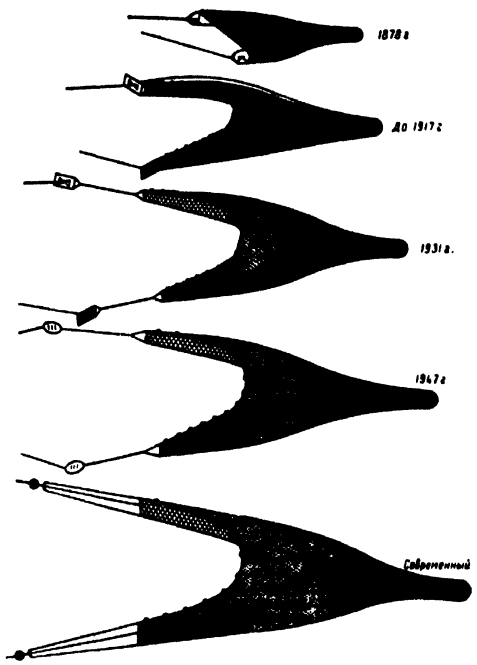

Fig. 1. Principal development stage of bottom trawl.

THE Soviet fishing industry is directed mainly toward active high sea fisheries practised from extremely sea-worthy vessels.

The main fishing gear is the bottom trawl (Fig. 1). The most widely used type is about 60 m long with a horizontal opening from 25 to 40 m; mouth to 3 m, towing at up to 3·5-5·0 knots.

Trawling is mostly at 150 to 250 m but sometimes, in the redfish (*Sebastes*) fishery the trawl is down to 500 m and deeper. Usually trawlers up to 800 to 1,000 hp bring in salted fish. There are now new freezer trawlers of 1,900 hp. The first Soviet sterntrawler, *Novator*, was built in Murmansk in 1948.

At present trawlers catch demersal species (such as cod, haddock and redfish) and pelagic species (such as herring and sardine). Trawling practice indicates that operations and trawl design for various species should be changed. For plaice, for instance, the large vertical opening of a trawlnet and high trawling speed are not required, while for herring the vertical opening and trawling speed are of primary importance. To a certain extent, a simultaneous increase in vertical and horizontal openings can be obtained by higher trawling speeds. In addition to adjustments by rigging the headline and footrope, the trawl parameters can be considerably changed by simply employing a more rational design of otter boards. The Soviet trawling fleet uses oval-shaped slotted otter boards (Fig. 2). These do not cut so deeply into the bottom, are more durable, relatively light in weight and have 19 per cent greater spreading force than comparable rectangular boards.

Midwater trawls

First attempts to use trawls to catch fish in midwater were made by Murmansk skippers as early as the 1920's, but results were poor. After many trials a new method of midwater trawling has been worked out which is

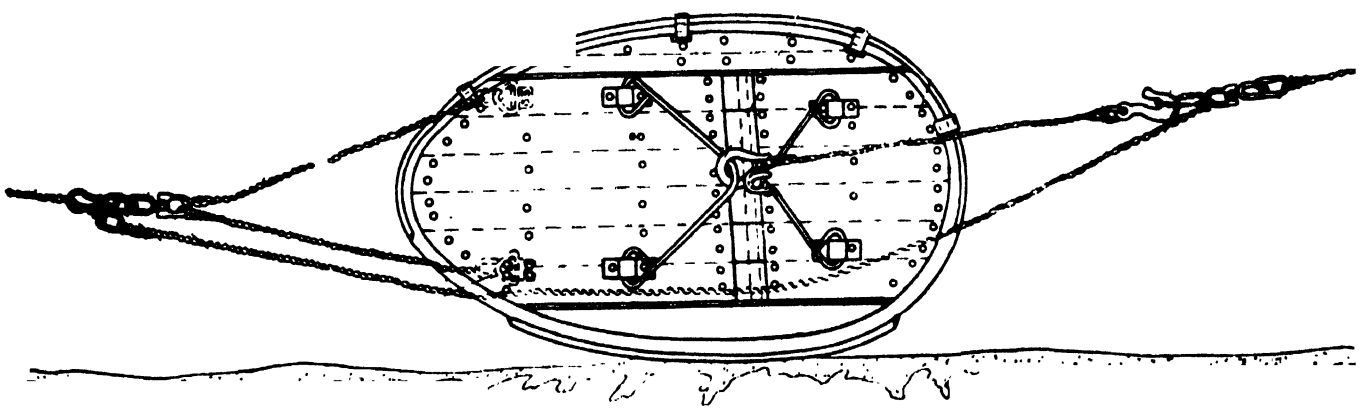

Fig. 2. Oval-shaped slotted otter board.

used by big trawlers on dense concentrations of Atlantic herring. In the North Atlantic catches after 30 minutes' trawling sometimes exceed 20 tons.

Apart from fish location aids, successful "aimed" midwater trawling requires special apparatus. A catch indicator which works on a hydro-acoustic principle is presently used in research work but it is not yet perfected for commercial use.

The transmitter is enclosed in a ball about the same size as the ordinary metallic trawl floats. This instrument is attached to the headline and connected by cable with the transducer installed in the codend. The receiver is on the pilot bridge. A more detailed description of the instrument may be found in the journal "Rybnoye Khozyaistvo" No. 7, 1959. Scientific research in trawl design development must be closely connected with studies of fish behaviour near trawl gear.

Gear testing

The determination of technical parameters—the openings of fishing gears, stresses and strains imposed on warps and rigs, shapes assumed by gears and so on—is a rather complicated task and requires special measuring devices, especially when operating at great depth.

Present methods and instruments so far allow study of only some of the factors involved, such as resistance to movement, depth of submersion and vertical and horizontal openings. The shape assumed by a trawlnet under different conditions and corresponding internal stresses in the gear are difficult to study during commercial fishing.

Experimental methods for laboratory investigations of trawl gear have been mainly oriented toward experiments in natural waters because model experiments in hydrocanals and wind tunnels with relatively small-sized models characterise only the qualitative aspect of phenomena, whereas the quantitative results obtained in this way are not sufficiently reliable.

There are several methods of conducting laboratory investigations of fishing gear in natural waters. At present the most advanced method, in the author's opinion, is that based on the use of a hydrodynamical installation on steel ropes. In this case a ropeway formed by two endless steel ropes is used (Fig. 3) running through snatch blocks in a natural basin with motionless water sheltered from wind. The endless ropes (1) are driven at a desired speed by an onshore electric winch (2). To these ropes is attached a pontoon (3) mounted on two floats. The tested gear or gear component (4) (trawl, etc.) is secured to the endless ropes under the pontoon by special hangings. During the process of towing the pontoon may shift its position in relation to the gear being tested. On the pontoon are measuring and controlling instruments (5) which register changes in parameters of the gear tested; movie cameras, searchlights and other aids.

The return movement of the pontoon is assured by a reverse operation of the winch. Speed of towing is regulated by a gradual change of winch r.p.m. through a frictional speed variator. This method permits testing both full-sized trawling gear and models scaled down to $\frac{1}{2}$ and $\frac{1}{4}$. The tests are conducted under conditions as near as possible to commercial fishing.

A special underwater dynamograph has been devised for measuring loading fishing gear operating at great depths. The working principle is based on the measurement of tractive effort reduced by a lever mechanism by means of a calibrated spring, and registered by a self-recorder supplied with multiplying device. The instrument consists of three essential parts: body, receiving mechanism and multiplying and recording mechanism. Its purpose is to measure stresses in ropes and

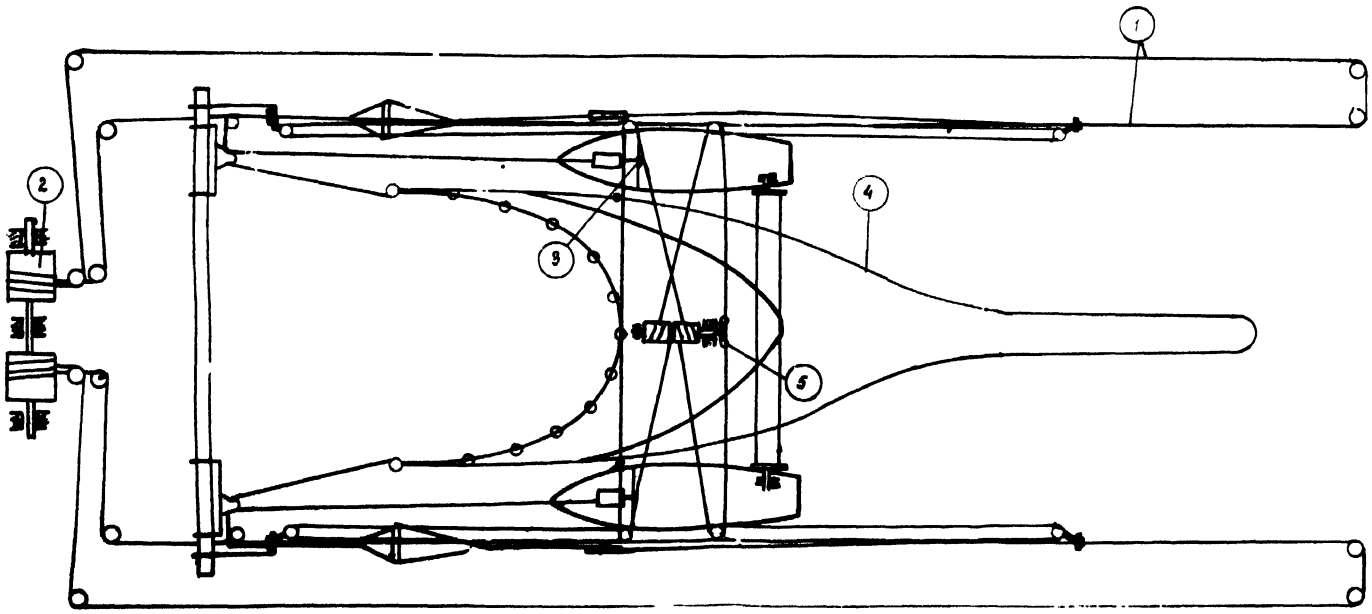

Fig. 3. A hydrodynamical installation on steel ropes.

Double-Rig Shrimp Beam Trawling

by
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and
A. Maton

University of Agriculture, Ostend

Abstract

Since 1959 the Belgian shrimp trawlers have steadily been converting from otter trawling to the double-rig beam trawling. All new shrimp trawlers have been especially adapted for this fishing method since 1962. The trawls used have, on average, a beam length of 8 m using a net of 550 meshes width of 26 mm mesh size in the upper part and 18 mm. in the codend. The whole net is made of nylon 420 R Tex. The paper describes the operational method and compares the catch efficiency of otter trawls versus double-rig beam trawls. The calculation of the resistance and effective mouth-opening for the two fishing methods shows that the theoretical advantage of double-rig beam trawls over otter trawls for shrimp fishing is of the order of 30 per cent. In double-rig operations in areas having strong tides, a hook-up with one gear is dangerous and the levering force acting at the boomtip can cause the vessel to capsize. Full details are given of a safety-rig incorporating a special safety hook. A survey of the catch results obtained with both methods in 1962 shows that, for the same horse-power, the double-rig method resulted in, on average, a 30 per cent higher catch, which compares well with the calculated 40 per cent greater horizontal opening.

Chalutage de crevettes avec double-chalut a perche

Résumé

Depuis 1959, les chalutiers à crevettes belges ont converti progressivement la pêche au chalut à panneau en pêche avec des chaluts à perches à double agréement. Depuis 1962, toutes les nouvelles unités de pêche aux crevettes sont adaptées spécialement pour cette méthode de pêche. Les chaluts ont une perche d'environ 8 mètres de long et utilisent un filet de 550 mailles d'ouverture dont les mailles ont 26 mm. dans la partie supérieure et 18 mm dans le sac. Le filet entier est fabriqué en nylon 420 R Tex. L'étude décrit la méthode d'opération et compare l'efficacité de capture des chaluts à panneaux avec celle des chaluts à double gréement. Le calcul de la résistance et de l'ouverture effective du filet pour les deux méthodes démontre qu'en théorie les chaluts à perches à double gréement sont supérieurs auc chaluts à panneaux de 30 pour cent. Cependant, au cours d'une opération à double gréement, dans les eaux à fort courant, un accrochement avec un des engins pounait être dangereux car la force s'exerçant alors sur le bout de la bigue risque de faire chavirer le bateau. Des détails concernant un gréement dont la sécurité est basée sur un crochet de sûreté sont fournis dans cette communication. Une étude des résultats de capture obtenus par les deux méthodes en 1962 montre que pour une même puissance, le système à double gréement produit des captures d'environ 30 pour cent plus importantes ce qui confirme assez bien l'augmentation théorique calculée pour une ouverture horizontale 40 pour cent plus grande.

Arte de vara doble para la pesca del camaron

Extracto

Desde 1959 aumenta el número de arrastreros belgas que pescan camarón que sustituyen el arte de puertas por otro de varas dobles Desde 1962 todos los arrastreros para la pesca del camarón se adaptan especialmente para este método de pesca. Por término medio, los artes tienen varas de 8 m y emplean paños de 555 mallas de 26 mm en la parte superior y de 18 mm en el saco, todos de nylon de 420 R Tex. El autor describe la maniobra y compara su rendimiento de pesca con el de los artes de puerta. El cálculo de la resistencia y abertura efectiva de la boca en ambos métodos demuestra que la ventaja teórica del de vara doble sobre el de puertas, en la pesca del camarón, es del orden del 30 por ciento.

Continued from page 208

cables at up to 350 m depth. Depending on the elasticity of the spring, the measured effort may vary between 500 and 5,000 kg. The measurements may be recorded continuously during 90 minutes. The instrument has a positive buoyancy so that its use does not greatly interfere with gear operation.

The vertical opening can be determined with the help of an instrument consisting of an expanding tank fastened to the upper point and a recording mechanism at the lowest point; the tank and the recorder are connected by an incompressible hose. The principle of this device being to measure the pressure created by a column of liquid contained in a closed system.

The manufacture of these devices present certain difficulties, since they have to be hermetically sealed. But they are much simpler and easier to handle than the equipment used in studies of fish behaviour and catching capacity of fishing nets, which require far more complex, long-term observations. Recently, such observations have been conducted with the help of aqualungs, bathyscapes and underwater television. In the U.S.S.R., a special submarine, *Severyanka*, is also used. The employment of the submarine permits long-term direct observations of fish near the gear and gives the opportunity to photograph the most interesting phenomena. Fig. 4 shows a photo of a trawl taken from the submarine.

Fig. 4. Photo of a trawl taken from a Russian submarine.

Cuando se emplean artes de vara doble en fondos de corrientes fuertes, los enganches y embarres son peligrosos porque la fuerza que actúa sobre el extremo de la botavara puede hacer que vuelque el barco. Se dan detalles completos de un aparejo con un gancho de seguridad especial. El examen de los resultados obtenidos con ambos métodos en 1962 demuestra que, a igualidad de potencia, el arte de vara doble dio, por término medio, capturas superiores en un 30 por ciento, lo que resulta muy favorable en comparación con la abertura horizontal calculada en un 40 por ciento mayor.

IN 1959 two traditionally equipped Belgian shrimp otter trawlers were converted to a double rig beam-trawling system. The operations were completely successful from the start, resulting in other vessels following suit, so that, by 1962, 28 of the 66 shrimp trawlers operating on the Belgian coast had changed over to double-rig operation. This conversion was the result of a scientific research, undertaken in charge of the Commission for Applied Scientific Research in Marine Fishery, presided over by gen. dir. F. Lievens.

Since 1962 new vessels are being built especially equipped for this type of operation. The fishery has a definite future and bigger vessels are under construction, such as those already operating from the Netherlands.

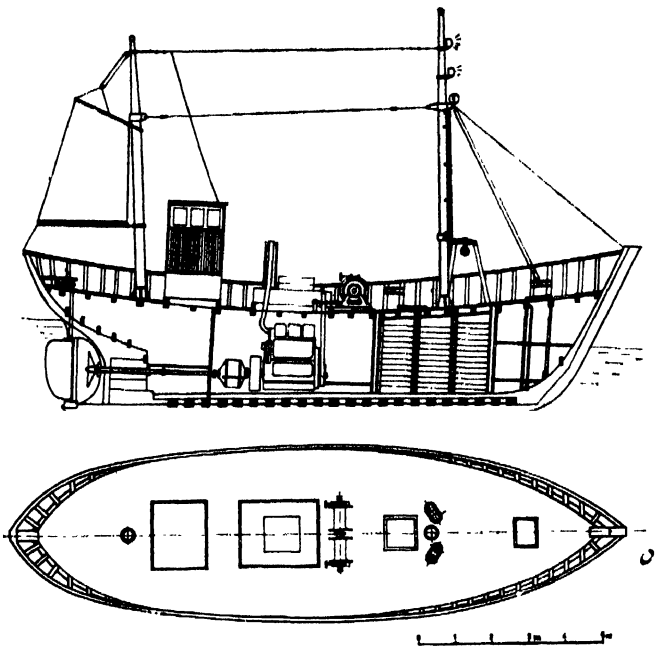

Fig. 1. Common Belgian shrimp trawler.

Vessels

The vessels converted up to the present have been mainly wooden with an overall length of 12 to 17 m, powered by 40 to 120 hp diesel engines (Fig. 1).

The conversion work consists mainly in erecting a steel mast based down to the keel which carries the two booms and the necessary rigging as shown in Fig. 2. Practically no changes are required to deck arrangements.

The winch used is the traditional double-drum otter trawl winch; the warps are now led over the booms to carry one complete fishing gear on each side. The booms are set to the required stance by tackles, which can be done by hand as long as the fishing gear is inboard; once fishing operations have started, the load is too high. For fishing, the booms are set to an angle of about 30° to the horizontal so that the footrope hangs just clear of the water (Fig. 3). During bad weather the boom is lowered to near the horizontal to improve stability.

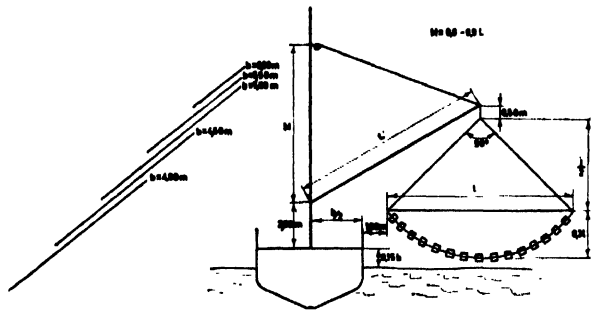

Fig. 3, Diagram showing the length of the derrick (L) as a function of the beamlength (l) and the vessel's beam (b).

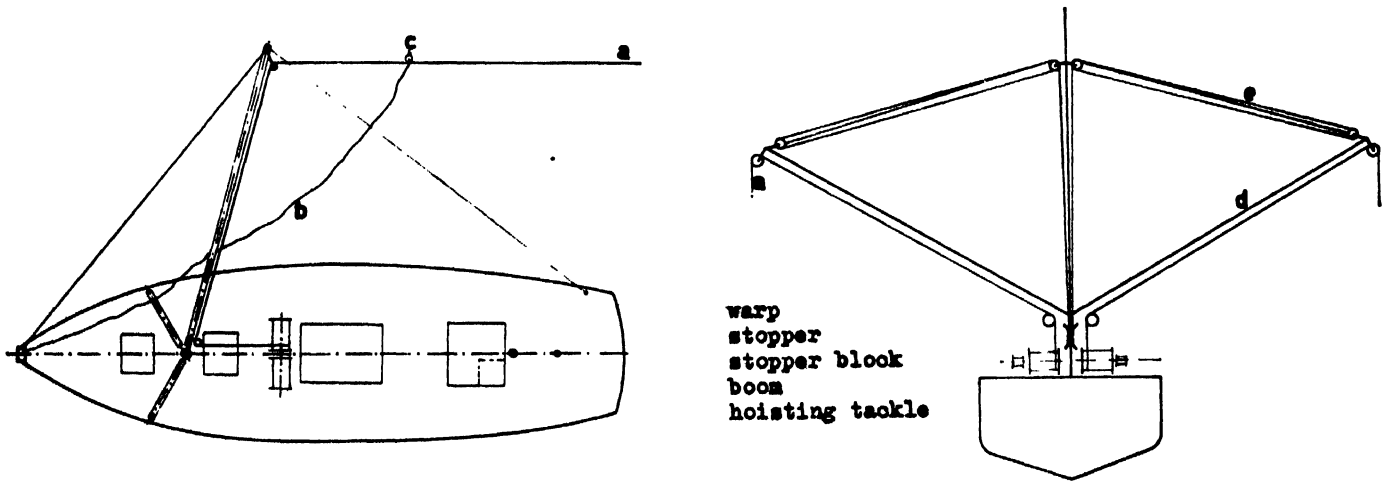

Fig. 2. Details of boom rigging on converted sidetrawler.

Adjustment of the position of the booms between hauls, according to fishing conditions, is done by heaving on the warping heads.

Several new double-rig vessels have lately been built for this work and the main difference between these new vessels and the older converted type seems to lie in the position and type of winch. The new winches are of the friction clutch type with four drums, two for the warps and two for topping the booms. The winch, furthermore, is now housed under the bridge within reach of the skipper so that the manipulation of the gear, regulation of the booms' position and steering of the vessel can now all be done from one position by one man. Only three men crew these vessels (Fig. 4).

By doing away with the skylight over the engine room and by leading the warps high above deck, these vessels now have a much larger working space on deck.

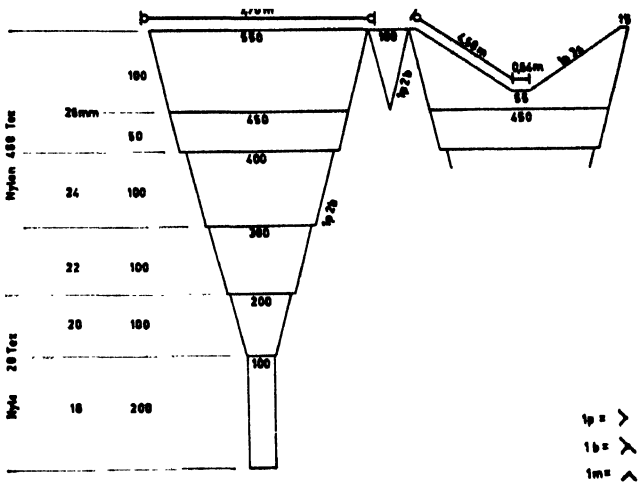

Fig. 5. Construction details of a beamnet.

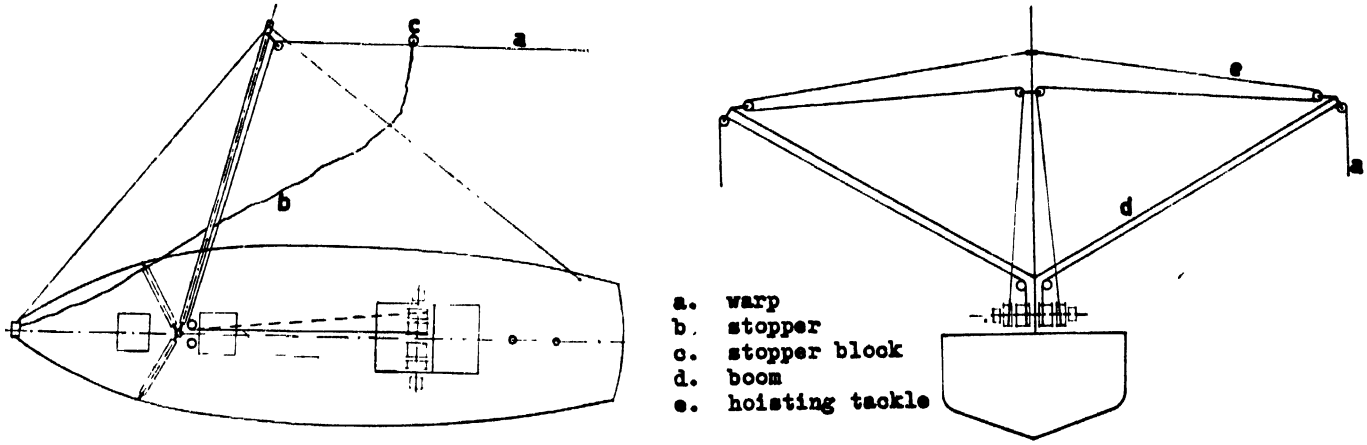

Fig. 4. Details of boom rigging on newly constructed double-rig trawler.

Gear

The net is the usual type consisting of an upper and lower piece seamed at the sides. Two wedges are inserted between the square and the lower wings to allow full lift (Fig. 5). The size depends on the length of beam. The more generally used type at present has a beam length of 8 m, a net width on top of 550 meshes of 26 mm mesh size in the upper part and 18 mm in the codend. The whole net is made of nylon 420 R Tex, except for the codend where 480 R Tex is used. The footrope, 9·80 m. long, is made of mixed wire rope of 14 mm diam. Full indications for assembling and mounting the net are given in Figs. 6 to 8. The above particulars cover both big and small nets as only the main dimensions differ, the general assembly of the nets being the same.

The length of beams differs according to the size of vessel and there is some slight constructional difference between ports (Fig. 9). The width of the beam shoe at the sole depends on the type of bottom fished, the softer the bottom, the broader the sole. Each beam shoe carries several eyes; one each for the headline, the foot-

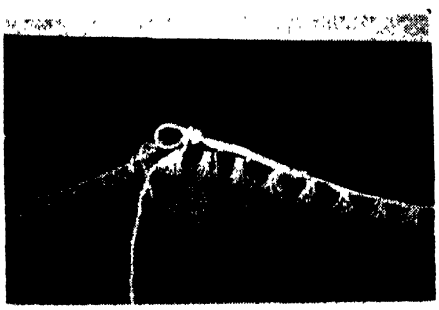

Fig. 6. Side panel and square with headline.

Fig. 7. Side panel and belly with bolchline.

Fig. 8. Junction of wing and bosom.

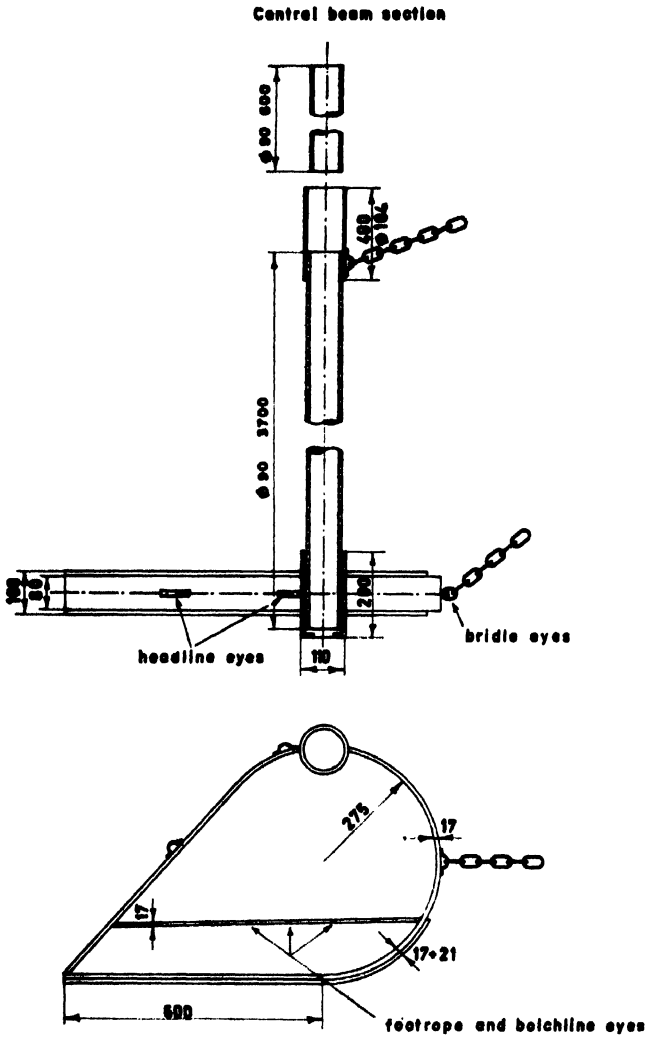

Fig. 9. Details of beam and beam shoe.

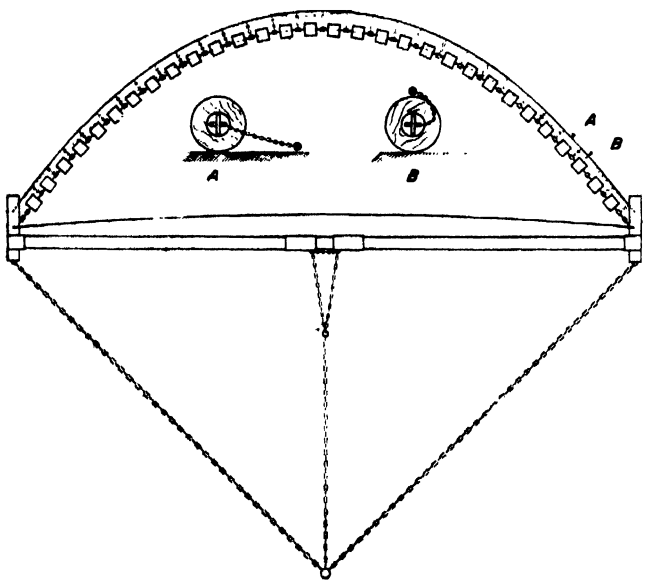

Fig. 10. Details of rig-up of beam and footrope. Inset A: normal bolchline length. Inset B: shortened bolchline.

rope and the bridle. The beam itself is normally constructed in three sections; the outer parts, which are secured by a chain, slide over the middle. The centre part is often of a lighter diameter than the outer parts so that when a hook-up occurs this part will bend and is then easily replaced without interference with the beam shoes. The footrope is made up of 13 cm diam wooden rollers or rubber discs, which are all joined by links at a distance of 30 cm. centre to centre. At each link there is a connecting chain to the bolchline. For the type of net under description 32 such rollers are used which together make up a length of 9·60 m. Under normal conditions the bolchline operates behind the rollers but in areas where much bottom trash, starfish, crabs, etc. are picked up, the bolchline is shortened so that it operates approximately parallel and above the rollers, allowing the bottom trash to pass between the rollers and under the net (Fig. 10). The relative tension on headline and footrope can be adjusted by attaching the footrope ends more or less forward at the beam shoes.

Operational method

At the fishing grounds both beamnets are hoisted ready for operation on the booms, which are set at an angle of approximately 30° and pointing a little more aft than abeam. The vessel steams ahead on a straight course, while wearing out both gears, until sufficient warp has been paid out in relation to the depth. During poor weather the beams are normally lowered to an almost horizontal position to improve stability. After hauling, the process described above is reversed and, when both nets are heaved to the boomtips, the vessel steams ahead for a short while to rinse the catch. Only the bat is then hauled on board with the gilson, the codend emptied and the gear prepared for the next haul.

Advantages of double-rig fishing

It can be shown that for the same engine power a larger area is swept with double-rig beam trawls than with one otter trawl.

The relation between the resistance of nets of identical construction can be expressed by:

$$\frac{R_1}{R_2} = \left(\frac{M_1 N_1}{M_2 N_2}\right)^2 \left(\frac{M_1}{M_2}\right) \left(\frac{\varrho_1 R_1}{\varrho_2 R_2}\right)$$

Where: R = resistance; M = stretched mesh size:
N = number of meshes in rounding;
ϱ = density of twines; R = runnage of twines;
v = towing speed.

Indices 1 and 2 refer to each net (otter trawl; double-rig beam).

When both nets are constructed of the same material and mesh size, and are towed at the same speed, the relation can be simplified to:

$$\frac{R_1}{R_2} = \left(\frac{N_1}{N_2}\right)^2$$

In the above equation N^2 can be substituted by $l \times H$;

when the relation of the length (l) of the headlines and the vertical height (H) of the nets is:

$$\frac{l_1}{l_2} = \frac{H_1}{H_2} = s \qquad s = \text{scale}$$

in which case $\left(\frac{N_1}{N_2}\right)^2$ can be written $\left(\frac{N_1}{N_2}\right)^2 = \frac{l_1 \times H_1}{l_2 \times H} = s^2$

The combined resistance of two small congruent nets whose total resistance is that of one big net can be given by: $2R_2 = R_1$

$$\text{therefore} \quad \frac{R_1}{R_2} = \frac{2R_2}{R_2} = 2 = s^2$$

$$\text{and } s = \sqrt{2} = 1{\cdot}41; \quad \frac{l_1}{l_2} = \frac{H_1}{H_2} = 1{\cdot}41$$

The length and height of the opening of one small net would then be 0·7 of that of the larger net having the resistance of two such small nets. The shrimp otter trawls used on the Flemish coast have very short wings and are therefore of practically the same construction as the beam trawls.

The length of the headline is on average about 10 m. and the net is attached to the boards generally without legs. The trawl boards used are 1·8 m × 0·9 m. The opening of such nets differs very little from the height of the trawl board and, as only few floats are used, the headline will hardly rise much above the board height. Using the opening of such a net as a basis, one could calculate the opening of two small beam trawls having the same resistance:

$$l_2 = 0{\cdot}7 \times 10 = 7 \text{ m.}$$
$$H_2 = 0{\cdot}7 \times 0{\cdot}9 = 0{\cdot}63 \text{ m.}$$

The height of the beam shoes, which represent the opening height of the beam net, is normally found to be 60 cm, which is very near to the height found for H_2. The horizontal spread of two beam nets would then be $2 \times 7 = 14$ m, and is therefore 40 per cent higher than that of one otter trawl having the same resistance.

Resistance of otter boards and trawl beams

Otter boards—Taking for granted that the otter boards have an angle of attack giving them an optimum sheering force for a certain speed, the resistance of the boards of 0·9 × 1·8 m having a towing speed of two knots can be approximated as below:

$$R = \frac{C.\ \varrho.\ A.\ v^2}{2}$$

C = specific resistance coefficient – 0·65

ϱ = density of seawater – 104 kg $\frac{\text{sec}^2}{\text{m}^4}$

A = area of boards in m².

v = speed in m/sec.; v = 2 knots = 1·028 m/sec

R = 58 kg.

The resistance for two boards works out to 116 kg.

Trawl beams—The resistance R of the cylindric part of the beam can be read:

$$R = \frac{C.\ \varrho.\ A.\ v^2}{2}$$

C = 1.

A. = 0·09 × 8 = 0·72 m²

v = 1·028 m/sec.

R = 39·5 kg.

In the same manner we can define resistance of the beam shoes with C = 1·3 as: R = 8·5 kg.

Total resistance of two beams with beamshoes = 2(39·5 — 8·5) = 96 kg.

Bottom friction resistance

The weight of one trawl beam with beam shoes is more or less the same as a pair of otter boards and the frictional resistance of an otter trawl should therefore be the same as that of the beam trawl. However, trawl boards plough through the bottom at an angle whereas, owing to the broad soles on the beam shoes, which act as sleds, the trawl beam glides over the bottom. It would therefore seem fair to assess that frictional resistance of two otter boards amount to about the same as that of two trawl beams. Summing up, it may be said that for a same condition of resistance, towing power and speed, the two beam trawls sweep 40 per cent more bottom, so that the increase in catch of shrimp and flatfish should also be about that amount; this is in fact corroborated by statistical analysis of the catches during one year (see later).

Advantages of the beam trawl

(a) The length of warp has much less influence on the beam trawl than on the otter trawl;

(b) The opening does not change during course alterations;

(c) The influence of tides is much less on a beam trawl than on an otter trawl as the opening is fixed whereas with otter trawls the resistance and shear of the otter boards, is highly affected when fishing in tidal areas;

(d) Shrimp trawling is usually carried out in muddy and soft bottoms. This does not affect the opening of the beam trawl as the opening is constant and the footrope catanary adjusted to an appropriate and constant "raking" light in the bosom. Such bottoms do affect the shearing effect of the boards so that the opening of the trawl varies, with the result that the footrope tends to dig in soft bottoms when the boards close;

(e) Double-rig operations allow easier adjustment of the gear to the fishing conditions as it is possible to conduct comparative fishing at all times because two nets are constantly in operation at the same time.

The direction of wind and tide has no influence on the shooting of the gear. As only the codend is hauled aboard, the whole can be mechanized, leading to faster operation with less crew.

Safety arrangements

One disadvantage of the method is that the stability of the vessel can be largely impaired when one of the trawls becomes hung-up by a bottom obstruction. The forces acting on the boomtop become so great that the vessel may capsize. This has in fact occurred on two occasions.

The forces arising from a hang-up of one net may be taken to culminate at a point at the top of the beam which is high above and far outside of the centre of gravity and tends to heel the vessel over. Investigations were carried out to develop a security release system which would guarantee stability under all conditions. Such a release must:

(a) Allow the forces acting at the top of the boom to be brought to a point lower down on the vessel, even when there are winch or other defects which prevent veering out of the warps;
(b) Transfer the forces to a point which allows the vessel to manoeuvre the gear clear of the obstacle.
(c) Allow the net to be hauled quickly and in a safe manner.

Fig. 11 shows such a security system which can be used on any type of double-rig vessel. In this system the warp coming from the winch is led through a block "a" attached far forward to the stern and runs over a boom-block "b" to the gear (Figs. 12 to 16). The boomblock is itself attached to a second block "c" by a runner and this runner is secured by a sliphook "d".

When the gear meets an obstruction the sliphook is released, which in turn releases boomblock "b", so that the towing forces now act on block "a", which ensures full stability of the vessel. The free net is then hauled over its own boom, after which the vessel is manoeuvred in the usual manner to free the hung-up gear from this obstruction. The gear is hauled hard on to block "a" where it is stoppered. Boom-block "b" is then hauled back to its position at the boomtip and the gear is further hauled in the usual manner.

Sliphook

The construction of the sliphook is given in Fig. 17. As can be seen, the gear consists of a holder B in which the hook H can turn freely round its axis E, but blocked by the lock F. Lock F itself has an axle which has two flat areas (as shown in detail, cross-section AB) and the axis carries handle h. The construction of hook H is such that the forces acting on it tend to turn it round its axis E, which is however prevented by F when the cross-section AB locks the hole G at the back end of hook H. By turning handle h, axis F releases the hook.

The axes E and F are constructed of stainless steel while the whole mechanization can be released by removing two slip pins so that maintenance and greasing are easy.

Economic results

During 1962 the Belgian Fisheries Services made a survey of the catches of shrimp trawlers. Data were collected on the engine power of the vessels, the number of hours

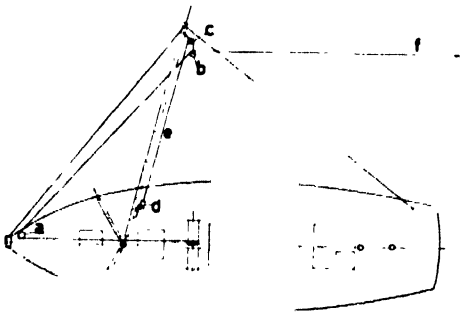

Fig. 11. Safety release rig-up. (a) forward block, (b) fishing block, (c) safety block, (d) safety hook, (e) safety runner, (f) warp.
Fig. 12. Warps (f) coming from the winch, running over the forward blocks (a) to the fishing blocks.
Fig. 13. Arrangement at the top of the boom, (b) fishing block, (c) safety block, (e) safety runner, (f) warp.

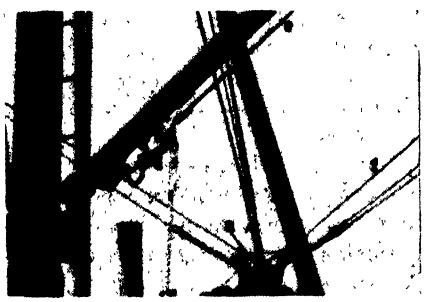

Fig. 14. The release arrangement with old type of sliphook (d) and runner (e). One can easily see the bowblocks (a) and the warps (f).
Fig. 15. The safety arrangement. The sliphook (d) was opened and the fishing block (b) came down. The warp (f) is pulling directly on the ship's bow (e) safety runner.
Fig. 16. The safety arrangement. When the net is hauled and stopped, the warps are loosening and the boomblock is hung in the top of the boom (h) bridle of the beamnet, (f) warp.

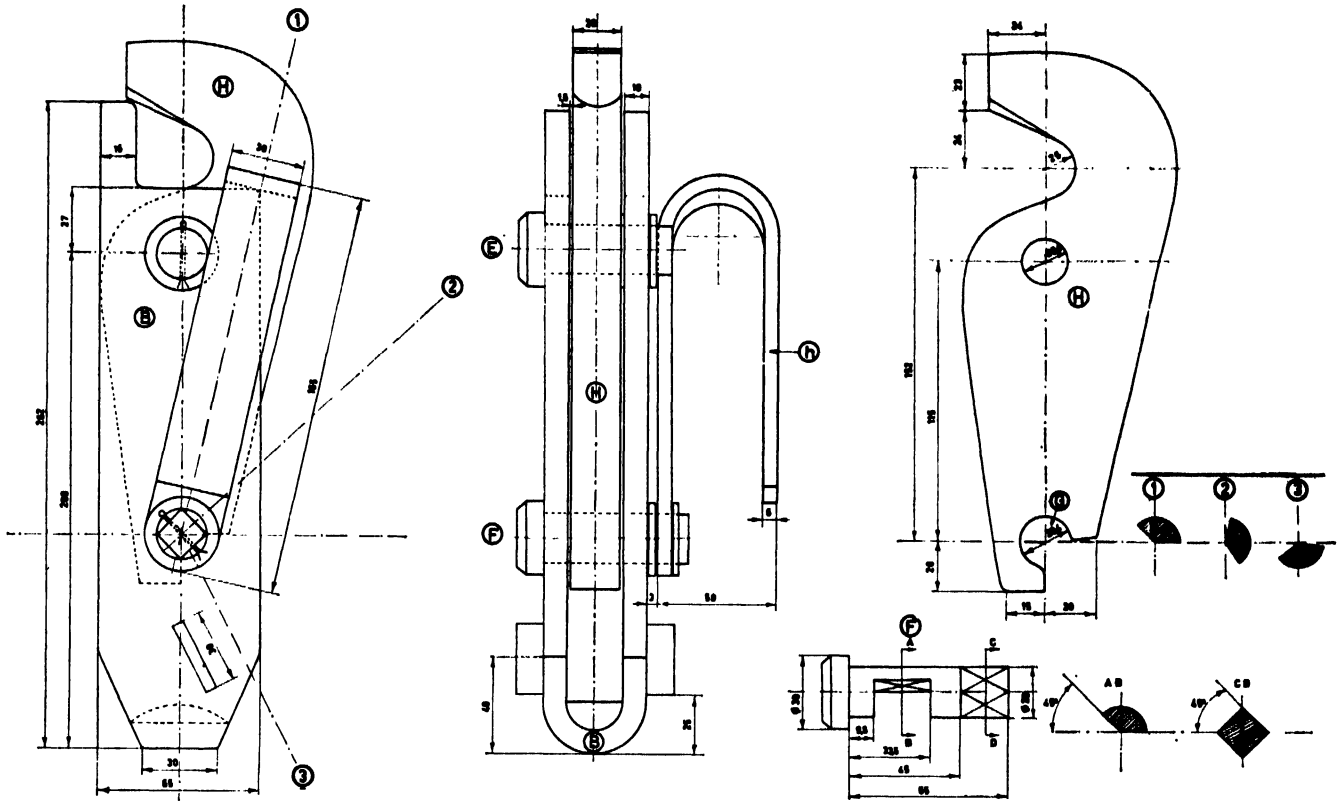

Fig. 17. Construction details of sliphook.

at sea for each trip, the number of hours spent in actual fishing operations and the total catch per trip. These data were analysed and statistically investigated for the purpose of ascertaining whether the double-rig fishing method was superior to the traditional otter trawl fishing method. The data pertaining to the fishing vessels belonging to the harbours of Ostend and Zeebrugge respectively were processed separately, partly because the fishing grounds for these vessels differed slightly but mainly because the relation of the number of beam and otter trawlers used was different.

Shrimp catch of Ostend vessels

The shrimp catches were analysed biometrically by two approach methods. In the first case, the average catch per hour for every week was calculated from the catch data for all vessels. In this calculation the time required to go to and from the fishing grounds was subtracted so that the catch per hour is in relation to actual fishing time. The data collected is given in Tables Ia and Ib.

The results of the biometrical analysis of these figures in respect of both double-rig and otter trawlers is given in Table II. As can be seen from this table, the double-rig trawlers during 1962 caught, on average, 6·21 kg of shrimp per hr, whereas the otter trawlers caught, on average, 4·49 kg per hr. The biometrical analysis shows that there is a significant difference (99 per cent) between the average catches calculated, in favour of the double-rig vessels, amounting to 1·72 kg per hr which works out to 38 per cent more catch.

Table II. Result of the variance analyses of the weekly averages in relation to catch per hour for both fishing methods (Ostend).

Type of variance	Degrees of freedom	Standard deviation of the mean	variance	F. calculated	F. Theoretical 95%	F. Theoretical 99%
Method	1	70,7954	70,7954	59,28	4,04	7,19
Weeks	47	197,3026	4,1979	3,51	1,61	1,96
Correction	47	56,1320	1,1942	-	-	-
Total	95	324,2300				

1. Correction term $C = \frac{514,40^2}{96} = 2756,3266$

2. Total = 3080,5566 - C = 324,2300

3. Methods = $\frac{(298,42)^2 + (215,98)^2}{48} - C = 70,7954$

4. Weeks = $\frac{5907,2584}{2} - C = 197,3026$

Average shrimp catch/hour for 1962

1. Average kg/hr (double-rig): $\frac{298,42}{48} = 6,21$ kg/hr

2. Average kg/hr (otter trawl): $\frac{215,98}{48} = 4,49$ kg/hr

Difference: 6,21 - 4,49 = 1,72 kg/hr

This difference is significant: F. cal. (59.28) > F.th.(7.19)

Table 1a - Details of shrimp catches by Ostend otter trawlers for 1962

Week	Number of trips per week	Average hp of vessels	Total trawling time per week.	Total catch per week (kg)	Average catch/hour per week
1	2	80	16,49	31	1,87
2	2	75	22,42	42	1,83
3	3	60	11,66	123	10,54
4	11	60	109,24	472	4,32
5	4	55	33,83	209	6,17
6	6	70	75,83	396	5,22
7	34	82	370,04	1,346	3,63
8	1	96	4,58	9	1,96
9	6	93	55,25	183	3,31
10	10	90	89,24	270	3,02
11	23	77	230,87	573	2,48
12	33	76	339,24	875	2,57
13	31	71	280,89	1,047	3,72
14	94	67	843,21	3,357	3,98
15	95	70	965,73	3,764	3,89
16	55	69	457,42	1,768	3,86
17	70	69	650,96	2,649	4,06
18	61	69	574,—	2,135	3,71
19	53	67	433,10	2,023	4,67
20	80	70	698,40	3,219	4,60
21	103	70	862,87	4,329	5,01
22	114	71	1.027,28	4,138	4,02
23	70	73	601,28	2,038	3,38
24	69	73	555,95	2,773	4,98
25	79	71	682,14	3,289	4,82
26	84	69	741,57	3,054	4,11
27	85	72	768,15	2,948	3,83
28	61	73	538,64	2,080	3,86
29	76	69	709,89	2,646	5,13
30	51	72	407,56	1,615	3,96
31	53	70	445,56	1,664	3,73
32	40	72	310,66	1,395	4,49
33	48	66	433,40	1,782	4,11
34	50	66	412,88	1,980	4,79
35	38	69	315,02	1,389	4,40
36	49	68	427,57	2,277	5,32
37	73	67	621,78	3,706	5,96
38	73	66	639,56	3,918	6,12
39	61	68	522,16	3,298	6,31
40	35	67	318,37	1,871	5,87
41	43	52	381,16	2,132	5,59
42	33	57	285,70	1,675	5,86
43	36	57	294,83	1,971	6,68
44	21	55	163,31	1,236	7,56
45	47	56	438,85	2,189	4,98
46	34	57	288,82	1,307	4,52
47	10	61	74,25	338	4,55
48	2	65	10,25	27	2,63

Table 1b - Details of shrimp catches by Ostend double-rig trawlers for 1962

Week	Number of trips per week	Average hp of vessels	Total trawling time per week	Total catch per week (kg)	Average catch/hour per week
1	3	93	20,83	111	5,32
2	3	66	45,17	294	6,50
3	4	80	50,25	281	5,59
4	3	79	15,50	109	7,03
5	9	75	79,17	526	6,64
6	4	77	46,75	401	8,57
7	9	67	107,90	613	5,68
8	2	99	14,50	73	5,03
9	4	77	48,58	257	5,29
10	3	76	38,51	147	3,79
11	5	83	75,83	295	3,89
12	8	77	102,16	476	4,65
13	4	77	26,58	150	5,64
14	18	72	162,31	981	6,04
15	14	76	167,47	888	5,30
16	10	62	87,50	435	4,97
17	16	74	163,15	961	5,89
18	15	73	149,89	733	4,89
19	9	78	81,67	565	6,91
20	15	77	132,66	897	6,76
21	18	78	144,72	966	6,67
22	21	78	194,74	986	5,06
23	14	79	116,14	432	3,71
24	10	76	82,57	461	5,58
25	18	77	159,49	962	6,03
26	22	75	191,63	842	4,39
27	20	77	187,49	942	5,02
28	19	78	172,85	896	5,18
29	21	76	187,60	1.001	5,33
30	15	77	103,42	514	4,97
31	14	76	121,91	583	4,78
32	14	81	119,01	662	5,56
33	12	83	115,99	580	5,—
34	14	76	112.67	687	6,09
35	21	76	176,24	906	5,14
36	15	77	131,92	893	6,76
37	16	65	149,75	1.066	7,11
38	14	79	135,91	1.037	7,63
39	17	79	149,83	1.205	8,04
40	14	74	126,91	1.053	8,29
41	14	58	126,83	1.381	10,88
42	21	77	188,15	1.833	9,74
43	12	76	107,43	924	8,60
44	9	71	58,30	596	10,22
45	14	77	127,18	1.313	10,32
46	17	79	167,09	1.241	7,42
47	7	77	73,56	500	6,79
48	4	69	56	209	3,73

The second method consisted of using the data concerning the daily catch of all vessels in the biometrical analysis involving 2,868 figures. The reason is that the first biometrical analysis depends on the average of weekly catches, which reduces the spread of the data considerably, because of the nature of these averages, and gives rise to the theoretical possibility that a significant difference could be found, where in fact there is none.

This second analysis, carried out over individual catch data, confirmed that there is a significant difference (99 per cent) between the catches of the double-rig trawlers and the otter trawlers (Table III).

In assessing the much larger catch efficiency of the double-rig system, trawlers with an average propulsion power of 76·2 hp were equipped with about 10 per cent more horsepower than the otter trawlers (69·1). On the other hand, the catching capacity of a vessel does not increase linear with the potential engine power. This

Table III. Result of the variance analysis of the daily averages in relation to catch per hour for both fishing methods (Ostend).

Type of variance	Degrees of freedom	Standard deviation of the mean	variance	F. calculated	F.Theoretical 95%	F.Theoretical 99%
Weeks	49	1513,5	30,88	6,69	1,35	1,52
Methods	1	1677,7	1677,7	363,92	3,84	6,64
Interaction weeks/ methods	49	2107,1	43,00	9,32	1,35	1,52
Error	2768	12753,6	4,601	-	-	-
	2867	18051,9				

1. Correction term $C = \frac{(14270,14)^2}{2868} = \frac{203.636.895,6196}{2868} = 71.003$

2. Total = 89054,9 - C = 89054,9 - 71.003 = 18051,9

3. Subclassed = 76301,34 - C = 5298,3

4. With the subclassed: 18051,9 - 5298,3 = 12753,6

5. Week: 72516,5-C = 1513,5

6. Method:

$$\frac{(3841,56)^2}{603} + \frac{(10.428,58)^2}{2265} - C$$

$$\frac{14.757.583,2}{603} + \frac{108.755.280,8}{2265} - C$$

$$24.473,6 + 48207,1 - C = 1677,7$$

7. Interaction 5298,3 - 1677,7 + 1513,5 = 2107,1

Average shrimp catch/hour for 1962

1. Average kg/hr (double rig): 6,21 kg/hr

2. Average kg/hr (otter-trawl): 4,49 kg/hr

Difference: 6,21 - 4,49 = 1,72 kg/hr

This difference is significant: F cal. (6,69)> F.th.(1,52)

was clearly shown in the study in the matter by De Poorter (1962). Yet even if we were to accept that the catch capacity of a vessel is in direct relation to its horsepower, the catch per hour of the double-rig trawlers would only be reduced to:

$$\frac{6{\cdot}21 \times 69{\cdot}1}{76{\cdot}2} = 5{\cdot}63 \text{ kg/hr.}$$

which would still mean a difference in catch per hour of $5{\cdot}63 - 4{\cdot}49 = 1{\cdot}14$ kg/hr, or 25 per cent, in favour of the double-rig shrimp beam trawling.

Vessels working from Zeebrugge

Here again a survey was conducted for all vessels; however, the number of vessels which had converted to the double-rig system was much greater and did not provide enough figures for otter trawlers to lead to a valied mathematical comparison between the two methods. During the whole of 1962, only 291 otter trawl catch figures could be collected, as compared with 3,223 for the double-rig system. The opposite occurred in Ostend where 603 double-rig catches could be compared with 2,265 otter trawl catches.

Notwithstanding, the collected data was analysed and it was found that the double-rig trawlers caught, on average, 8·88 kg of shrimp, compared with 5·63 kg per hr for the otter trawlers, resulting in a difference of 3·25 kg per hr, or 57 per cent in favour of the double-rig trawlers. These figures are, however, not directly comparable as there exists an appreciable difference in average horsepower between the vessels in Zeebrugge. The average horsepower of the double-rig vessels was found to be 87·7 whereas that of the otter trawlers was 76·2, so that the average horsepower of the latter is about 25 per cent lower than the double-rig trawlers. This must, of course, be taken into account and when the catch per hour of the double-rig trawlers is reduced for this difference in horsepower the comparable catch becomes:

$$\frac{8{\cdot}88 \times 67{\cdot}2}{87{\cdot}71} = 6{\cdot}8 \text{ kg/hr.}$$

From the above it is clear that the catch of the double-trawlers is still superior to the otter trawlers by 1·12 kg per hr. It must be noted that the comparison is based, however, on a linear increase of catch with the horsepower of the vessel, which is by no means sure.

Conclusions

The survey conducted has shown that the double-rig shrimp trawlers operating from Ostend have a catch efficiency that is about 38 per cent higher than that of the traditional otter trawlers. Even when reducing the actual catches in respect of the difference in horsepower, the net higher catches of the double-rig trawlers can be expected to be 30 per cent. This 30 per cent increase in catch shows a good relation to the theoretical 40 per cent increase in horizontal opening of two beam trawls as compared with one otter trawl.

The double-rig method has recently been introduced on fish trawlers and is being applied more and more to the catch of flatfish. There is not enough data available at present to assess whether the increase in catch of fish is of the same order as for shrimps.

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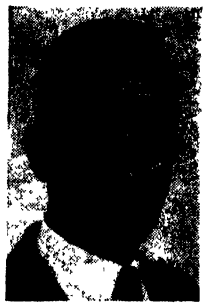
Discussion on Bottom Trawling



A. R. Margetts

Mr. A. R. Margetts (UK) Rapporteur : The bottom trawl itself has changed remarkably little over the years and those changes that have been made are certainly not commensurate with the changes which, in the same period, have occurred in trawling vessels. The big development in recent years had been in midwater trawling, while more attention has been paid to developing from something like a standard bottom trawl special trawls for particular types of fish and fisheries. Both experience and experiments have shown that two rather similar trawlers with not very different trawls could take catches of quite different composition as regards both quantities and species of fish. Since the last Congress there has been progress in fitting instruments to gear to discover the mechanics of how it works. A common assumption in efforts to improve bottom trawls has been that to increase the mouth area of the trawl would increase the catch. The validity of that assumption is perhaps questionable.

The approaches are broadly divisible into two groups. The first start from the bottom or bottom trawls and work up by increasing the headline heights, as instanced by Crewe, Dale and Hamuro. The second group start from the truly-midwater trawls and work down by adapting them for fishing just off the bottom, as described by Schärfe and Okonski.

Dickson outlined the steps taken to find out by instruments the dimensions and operating forces in respect of a standard bottom trawl. The measurements of the standard Granton trawl given, and generally accepted as typical, are that the spread of the net (with a 24 m headline) is of the order of 16 m with headline height or vertical opening of about 2 m, the whole towed at a load of about 7 tons. Hamuro also measured existing trawls in his investigations, and to achieve similar knowledge the Russians, as described by Treschev, had photographed a trawl from a submarine. It would be interesting to know more of their technique.

Hamuro was dissatisfied with the behaviour of otter boards and designed improvements. Crewe and Dale and Moller also detailed their investigations into the hydrodynamics of otter boards. Hamuro measured the flow of water in the trawl and showed how much water undesirably spilled out of the front of the net. He then redesigned the net to successfully reduce this and improve flow characteristics. Crewe outlined how otter boards and warps behaved and showed the effect of camber in improving efficiency of the boards while requiring a different fishing technique. Instruments showed even that warps could appear crossed at the trawler yet the otter boards be still holding the net somewhat open. Crewe studied the netting component of the trawl and tackled the problem of netting resistance at the low angles of incidence occurring in the trawl; this was relatively very different from that of sheets of plane netting at big angles of incidence such as had been investigated in most of the tank experiments hitherto. There was a striking similarity in the development of trawls by all authors in this section; each had improved otter boards and two or three used a long leg or bridle system allowing floats to give a vertical opening to a big net which had side panels of netting to allow it to be opened. In the making of these bigger nets, new synthetic materials had helped by maintaining the necessary strength with finer twines which gave less drag. The opening of Hamuro's new net measured 26 m wide by 11 m high, an enormous increase on the 16 m × 2 m mouth of the Granton trawl.

On the mechanical side, big advances had been made and the engineers now knew enough to develop any particular trawl required. On catching, Hamuro, with his 26 m × 11 m trawl compared with the Granton, claims that his trawl (which had been adopted for commercial fishing) has given a catch increase of 150-200 per cent but he does not mention what fish are caught. If they are mainly bottom species it may be that it is only the spread which is mostly responsible. Schärfe, in his midwater trawling, at first got poor catches, but he persisted and was rewarded by success in catching herring in a couple of hauls at Iceland. It would be wrong to expect any newly developed gear to start catching at maximum efficiency straight away. Time must be allowed for a new gear to be properly tried and worked with the co-operation of skilled fishermen before final judgment is passed on it.

It is abundantly clear from many papers that the link between gear development and behaviour of fish in relation to that gear is a very tenuous one and one which must be strengthened. We still do not properly know how or why a trawl catches fish. We know that herding of fish in front of the net does occur but we are not sure how it occurs and this we must know in order to make more efficient gear. Bottom trawling has the advantage over midwater in that there is the bottom against which to trap the fish. But there is always the problem of how to trawl rough ground. Overfishing and experience of fish distribution, drives or draws fishermen to rough ground, and there is need for both rough and smooth ground trawls.

Contributions by Kreutzer and Wathne might well be important for future development. Earlier it was thought that electric fishing in the sea would not be practical. Now, however, Kreutzer has shown that pulsed DC can overcome a lot of difficulties. He has already, perhaps, eliminated fish behaviour as a factor in trawling by electrocuting the fish in front of the trawl which then swept them up. His first electrified trawling results indicated improvements in catch but more thorough testing is needed. Wathne used pulsed DC (a different technical method of pulsing) to disturb shrimps from the sea bed and make them jump into the path of the trawl.

In his paper Nicholls urged more co-operation in gear development by the inclusion of biologists as well as technologists, engineers and fishermen. A start had been made in that direction in Britain by a trawl development programme involving the Saunders Roe Division of Westland Aircraft Ltd., and in Europe there is an unofficial international group working for the development of pelagic fishing methods, which consisted of actively interested workers exchanging ideas and experiences.

Mr. Robert Lenier (France): It is obvious that the more bottom trawls work the fishing grounds the more will they debilitate the bottom of the sea by destroying the natural feed and larvae. To avoid that damage by heavy trawls, they should lighten the trawling gear and preserve within the

territorial waters a three-mile limit within which trawling should not be permitted and so protect the spawning grounds.

Mr. Margetts: I must flatly contradict Mr. Lenier that trawling badly damages the sea bed and its food value. Experiments in the United States, Britain and Denmark were convincing that even heavy trawling did not appreciably damage the grounds or most of the animals contained in the surface of the sea bed. The sea bed was not denuded of food. Grounds had been worked for centuries and were still producing fish. Further, most spawning grounds were not inside the three-mile limit, but there were nursery grounds in inshore waters and some fish could be protected by keeping trawlers away from those nursery grounds.

Mr. J. G. de Wit (Netherlands): Our fishermen are using the double-rig beam trawl the same as the Belgians for shrimps (described by Verhoest) but they also use it for flat fish. This was a very old rig which had come into use in an extensive way. Our fishermen used a number of tickler chains in front of the footrope—up to five—and this exerted a tremendous force first on the shoes and afterwards on the beam, and bending of the beam was causing a lot of trouble. The beams were up to 11 metres in length and it was therefore essential to rig the beams so as to minimise the bending movements as much as possible. There was a strong tendency to use the double rig beam trawl for stern trawling. The small trawlers using double-rig beam trawls had only one mast. If this was placed aft, the vessel was easily handled, but when working in strong currents the mast should be put forward as much as possible in order to give greater manoeuvrability, so that in the event of the gear becoming fast and the boat swinging in cross-currents it would be less in danger of capsizing.

Mr. J. A. Tvedt (UK): Many skippers use different types of gear on the same grounds for the same purpose and each swears by his particular choice. Obviously they cannot all be right. It was therefore important to try to find an improved standard gear. As regards the desirable headline height and net size, his company had worked out a design for a trawl to work a little way off the bottom. They had reduced the heavy ground gear so that it will partly roll and partly skim the surface without scooping up the bottom. To further reduce the churning up of the bottom their trawl boards were made more buoyant and operated lightly over the ground and were given increased lift. They did not subscribe to the theory that sheer net size was the way to get a better catch. They had gone the other way and were trying to produce a reasonable standard mouth area but they had changed the proportions of the mouth and had settled on something like twice the Granton headline height and had also reduced the twine in the trawl to the minimum size they thought necessary to withstand rough usage. This design had been tried in laboratory tests and they expected to have practical results shortly. They expected to get greater spread with it.

Mr. D. L. Alverson (USA): Fishermen have to choose whether they are going to catch fish on the bottom or above it and fishermen in some areas carry two nets: one for flounders on the bottom and one for redfish higher above the ground. As to raising the trawl a little off the bottom to preclude damage, his department had carried out some experiments. For their specific purpose they towed three ways: (1) on the bottom, (2) half a metre above the bottom, and (3) with a box form of trawl just above the bottom, for towing half a metre above the bottom they caught only one-eighth of the quantity of the fish they caught on the bottom.

When fishing alongside some Russian vessels in the northern area they found that the Russians rigged their gear so that they had no weight on the groundrope itself but used a number of droppers like sash weights each fastened on a fathom of rope so as to just touch the bottom. They then waited till their netzsonde showed the redfish had moved off the bottom and then began towing and got good catches. When the Americans in that same area put their gear on the bottom they got very little fish. By timing their operation the Russians did very well.

Dr. Miyazaki (Japan): A company in our area which specialises in shrimp trawling uses two methods. In the first method a bottom trawl is raised to midwater and in the second the trawl is in midwater from the beginning. In the first case, if the presence of shrimp is known, the trawl is raised from the bottom while carefully watching the net conditions through the netzsonde. The ratio between the depth and the warp length should be between 1 to 2·5 and 1 to 2·3 and the difference between the upper and lower otter board back-strops about 2·50 m. In the second method, with the trawl in midwater from the beginning—it is generally about 10 metres above the seabed—the ship's speed must be maintained after shooting the net. The netzsonde is again carefully used. If the school of shrimp happens to be above the net an adjustment should be made by the same method just described. When the school is at a lower level, the adjustment has to be made by slowing down the engines. The maximum speed of lifting the net is 12 metres per minute and the average about 9 metres per minute. Midwater trawling can be carried out within a range of about 40 metres by continuous adjustment in the vertical distance. No precise formula exists for these operations but the greatest efficiency depends on the captain's experience and skill.

Mr. Eldon Nichols (USA): Breaks in international cables due to trawling are 40 to 50 a year in the North Atlantic alone. Any one break might interrupt 100 telephone conversations or cablegrams and it would take a boat sometimes a week to get to the cable to mend it. A new cable had been laid across the Atlantic between Britain, Iceland, Greenland and Canada for International Air Control. Since last October up till May there had been six breaks in that cable because of trawling and it was still out of action. (Nevertheless he hoped delegates at the congress who were flying the Atlantic would have happy landings!) In his paper he stressed the desirability of improving trawl board design if at all possible so that they would not hook and catch the cables. If the otter boards could be kept off the bottom it would help, or alternatively the points of attachment might be made so that they would fend off rather than hook on the cables.

Mr. Harper Gow: Your company and mine have been in contact over the years on this problem. These cables spread completely haphazardly over the best fishing grounds in the world and the surprising thing really is that so few get caught by trawlers as they carry out their operations.

Mr. Nichols: The number is being reduced by improved methods and some cables are being lifted.

Mr. P. R. Crewe (UK): The present method of attaching the warps to the otter boards is designed to give them some

sort of stability. There was probably more hope of avoiding damage to the cables by taking the otter boards completely off the bottom but this might have disadvantages in regard to fish behaviour, but it might also have advantages. He had never done any work on fish until required by the research work for the White Fish Authority, the British Trawlers Federation and the British Government to take part in the recent investigation. They were not charged with investigating fish behaviour but only the engineering aspects of trawl boards and nets. The nature of their project nevertheless made it necessary to do some general investigation regarding the trawls and their mouth area and so on, and he had attempted to develop general mathematical theories as to how they behaved. These were set out in his paper which gave a range of values for mouth areas and the warp lengths.

Dr. Schärfe (Germany): In the Mediterranean the sweep: lines attached to the otter boards are 120 fathoms in length and are thus so long that they make their trawl something between a trawl and a Danish seine. Without the long sweeplines their catch would decrease very much.

Mr. A. Gronningsaeter (Norway): The cable routes should be marked by electronic devices in the form of a grid so that they can be avoided.

Mr. Nichols: The United States authorities mark the cables on all the official charts that are now issued. These charts will also show the Loran grid and he understood that the British Admiralty's charts in preparation would show the cables as well. The cable companies had distributed tons of Shifting the point of attachment might not provide the right charts throughout the world to help trawlers know where cables were and avoid them if possible. Some countries had given excellent co-operation but in others progress was very slow. They could not expect that it would ever be 100 per cent and that was why they looked, if possible, for the fishing industry to do something about fishing gear.

Mr. Dennis Roberts (UK) agreed with Dr. Schärfe that otter boards and sweeplines were essential. It was their experience on the Humber that skippers who used longer bridles caught more fish. Certainly expenses went up. For bottom trawling to be successful they would have to be on the bottom and use maximum length of bridles.

Mr. Margetts summing up said that many of the points made related to fish behaviour and they were questions to which biologists and technologists believed the answers to be important for ensuring future development. On existing engineering information, it was possible to design nets to definite specifications, but what they did not know were the particular values for any parameter as being most suitable for catching fish. They required to know much more about fish behaviour and he hoped that that theme would be developed in other sessions of the Congress. Trawl designers should heed the comments about submarine cables, but the most helpful immediate measure will probably be the accurate charting of cable positions, particularly with fixes by such navigational aids as Loran, so that fishermen might keep away from them. Mr. Alverson's point showed that, in some fisheries, if the net was raised off the bottom, the fishing would become non-paying, and that problem related to fish behaviour as well as to fish distribution.

One-Boat Midwater Trawling from Germany

Abstract
From 1958/59 the German efforts towards the development of midwater trawling for herring were intensified. The present paper deals only with the one-boat technique for which special nets, otter boards and a net-depth telemeter ("netzsonde") were improved step by step. The trials were started with small (24-m length and 150 to 180 hp) trawlers and gradually extended to the big long-distance sterntrawlers with a stern ramp (70 m length, 2,100 hp). The objective was to develop a trawl gear suitable for on-the-bottom trawling, near-the-bottom trawling as well as real midwater trawling. The gear was designed for operation with normal side- or stern-trawlers without requiring additional auxiliary gear or special training of crews. The trawlnets were made of nylon continuous multifilament twine. The first model was a two-seam, high-opening design requiring three bridles at each side and with 500 to 800 meshes (200 mm stretched) circumference. Recently a new four-seam model with 1,200 to 1,400 meshes circumference and rectangular cross-section (side panels narrower and shorter than top and bottom panels) gave very satisfactory results. Curved all-steel trawl boards (Süberkrüb) proved to be better than combined steel-wood construction. Sizes of up to 6 m^2 each have been used, depending on the size of the vessel and the gear. The "netzsonde" telemeter is an echo sounder connected by cable with a transducer mounted on the headline, and gives information regarding the net-depth, the opening-height and fish distribution in and below the netmouth. Such information is of value for gear studies as well as for commercial fishing. The catching efficiency of the one-boat midwater trawl was satisfactory for spawning herring, but at first rather poor for non-spawning herring in comparison with the two-boat trawlers. Improvements to the design and size of the net and boards increased the distance between the boards from about 30 to 50 m up to 65 to 90 m, and resulted in remarkable increase of catching efficiency for non-spawning herring. Comparative fishing trials indicate that this improved one-boat trawl will catch practically the same as two-boat trawls of comparable size. Herring has been fished experimentally in the North Sea, the English Channel and the Irish Sea, with main emphasis on the Norwegian coast (Egersund and north up to about 60°N). In recent trials (February 1963) promising catches of non-spawning herring were also obtained off South Iceland. It is expected that the new one-boat trawling technique will become valuable when the conditions for bottom trawling are less favourable. Apart from herring, also cod, saithe, mackerel, sardines and other clupeids have been caught in quantities and it seems likely that other fish stocks could also be fished with this gear.

by
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Chalutage pélagique a un bateau, en allemagne

Résumé
Depuis 1958 les Allemands ont intensifié leurs efforts en vue de développer le chalutage pélagique pour les harengs. La présente étude ne traite que du chalutage pélagique à 1 bateau, pour lequel des filets spéciaux, des panneaux et des télémètres de profondeur des filets (Netsonde) ont été améliorés progressivement. Les essais ont commencé avec des petits chalutiers (24 m de long et 150 à 180 cv) puis ont été étendus aux grands chalutiers hauturiers pêchant par l'arrière (70 m de long et 2,100 cv) ayant une rampe à l'arrière. L'objectif était de développer un engin pouvant opérer sur le fond, près du fond, aussi bien qu'entre deux eaux. Les engins ont été construits pour des chalutiers normaux opérant par le côté ou par l'arrière, sans nécessité d'installation supplémentaire d'accessoires auxiliaires ni entraînement spécial de l'équipage. Les filets ont été fabriqués en fil de nylon continu, multifilaments. Le premier modèle était un chalut à grande ouverture, à deux coutures avec trois entremises de chaque côté et avait de 500 à 800 mailles de circonférence (200 mm maille étirée). Récemment un modèle à quatre coutures, de 1200 à 1400 mailles de circonférence, de coupe rectangulaire (panneaux latéraux plus étroits que les panneaux supérieur et inférieur) a donné des résultats très satisfaisants. Des panneaux de chalut, courbés (Süberkrüb) construits tout en acier se sont révélés supérieurs à ceux d'acier et de bois combinés. Suivant la longueur du bateau et la taille du filet, des surfaces ayant jusqu'à 6 m2 chacune, ont été utilisées. Le télémètre Netsonde est un écho-sondeur relié par câble électrique à un émetteur monté sur la ralingue supérieure. Il donne des informations concernant la profondeur du filet, son ouverture verticale et la répartition du poisson à l'intérieur et au-dessus de l'ouverture du filet. Ces informations sont de grande importance pour l'étude des engins de pêche et pour la pêche commerciale. En comparaison avec celle des chaluts à deux bateaux, l'efficacité de capture de ce chalut pélagique à un bateau était satisfaisante pour le hareng en frai mais beaucoup moins pour le hareng ne frayant pas. Des modifications apportées au dessin et aux dimensions du filet et des panneaux ont augmenté de 30-50 m jusqu'à 65-90 m la distance entre les panneaux et ont permis un accroissement remarquable de l'efficacité de capture des harengs ne frayant pas. Des essais de pêche comparative indiquent que ce chalut à un bateau amélioré peut, pratiquement, pêcher autant que les chaluts à deux bateaux de dimensions comparables. La pêche au hareng a été conduite expérimentalement dans la Mer du Nord, la Manche et la Mer d'Irlande mais surtout sur la côte Norvégienne (Egersund) et au Nord, jusqu'à 60°. Au cours d'essais récents (février 1963) on a obtenu, au Sud de l'Islande, de bonnes captures de harengs ne frayant pas. On suppose que la nouvelle technique de chalutage à un bateau deviendra très intéressante surtout lorque les conditions de chalutage sur le fond seront mouns favorables. Outre les harengs, des cabillauds, des morues charbonnières, des maquereaux, des sardines et autres clupéidés ont été pris en quantités et il semble que d'autres espèces de poissons pourraient aussi être pêchées par cet engin.

La pesca al arrastre entre dos aguas con una embarcación en alemania

Extracto
Desde 1958/59 se han intensificado las experiencias alemanas para perfeccionar la pesca del arenque con artes de arrastre flotantes. Esta ponencia se ocupa solamente de la técnica en la que se emplea una sola embarcación, y para la cual se mejoraron poco a poco redes y puertas especiales y un telémetro que indica la profundidad a que está el arte (netzsonde). Los ensayos se iniciaron con arrastreros pequeños de 24 m de eslora con motores de 150 a 180 hp y gradualmente se emplearon grandes arrastreros de altura con rampa a popa (70 m de eslora y motores de 2,100 hp). La finalidad era encontrar un arte que sirviera para pescar en el fondo, cerca de éste y entre dos aguas, y que lo pudieran emplear los arrastreros normales que pescan por el costado o por la popa sin tener que instalar material auxiliar adicional o capacitar especialmente a las tripulaciones. Las redes eran de nylon de filamentos continuos. El primer modelo construído consistía en un arte de dos relingas laterales, gran abertura en altura, tres bridas en cada lado y de 500 a 800 mallas de 200 mm de circunferencia. Recientemente un nuevo modelo de cuatro relingas laterales de 1,200 a 1,400 mallas de circunferencia y sección rectangular (los paños laterales son más estrechos y cortos que los superiores e inferiores) dio muy buenos resultados. Las puertas de acero cuvado (Süberkrüb) resultaron ser mejores que las mixtas de acero y madera. Se han empleado hasta de 6 m^2, según las dimensiones del barco y del arte. El telémetro "netzsonde" es una ecosonda conectada mediante un

cable a un transductor montado en la relinga de corchos que da información respecto a la profundidad a que está la red, su abertura en altura y distribución de los peces ante la boca y debajo de ella. Estos datos son de importancia para los estudios de los artes y en la pesca industrial. El rendimiento de pesca de un arte flotante arrastrado por una embarcación fue satisfactorio en el caso del arenque en desove, pero al principio, y con respecto a las parejas, no lo fue para el arenque que no desova. La mejora de la forma y de las dimensiones del arte y de las puertas incrementó la distancia entre éstas de entre 30 y 50 m hasta 65 y 90 m y produjo un notable incremento del rendimiento de pesca de arenque que no desova. Los ensayos de pesca comparativa indican que este arte mejorado para una sola embarcación pesca prácticamente lo mismo que una pareja de dimensiones análogas. El arenque se ha pescado experimentalmente en el mar del Norte, Canal de la Mancha y mar de Irlanda y, sobre todo, en la costa noruega (Egersund y hacia el norte hasta cerca de los 60°N). En ensayos recientes (febrero de 1963) al sur de Islandia también se obtuvieron capturas alentadoras de arenque que no desova. Se anticipa que la nueva técnica de arrastre con una embarcación adquirirá gran importancia cuando las condiciones para la pesca en el fondo sean menos favorables. Además de arenque, también se han pescado importantes cantidades de bacalao, abadejo, caballa, sardinas y otros clupeidos y es probable que también pudieran capturarse en estos artes otras poblaciones icticas.

A schematic view of the prototype trawl gear developed during 1958/59 and thoroughly tested later is given in Fig. 1. Details of the otter board and of the one-boat midwater trawl net (two panels) are given in Figs. 2 and 3.

This gear, tested in different sizes and with different types of trawlers, performed apparently satisfactorily from a technical point of view. On several occasions during trials, and also on commercial fishing trips it gave satisfactory catches of spawning herring in the North Sea, the Irish Sea and the English Channel, and of cod off the west coast of Greenland. However, extensive

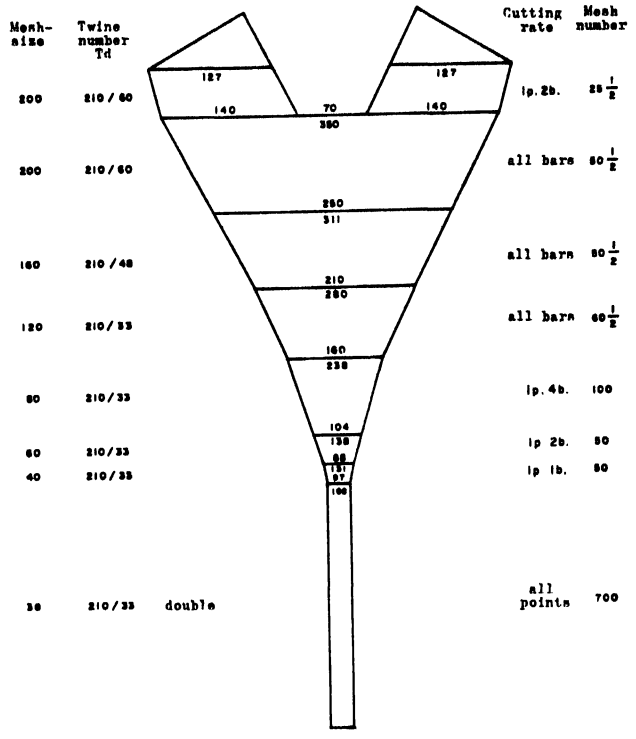

Fig. 3. One-boat midwater trawlnet, two-sideseam type, consisting of two equal panels.

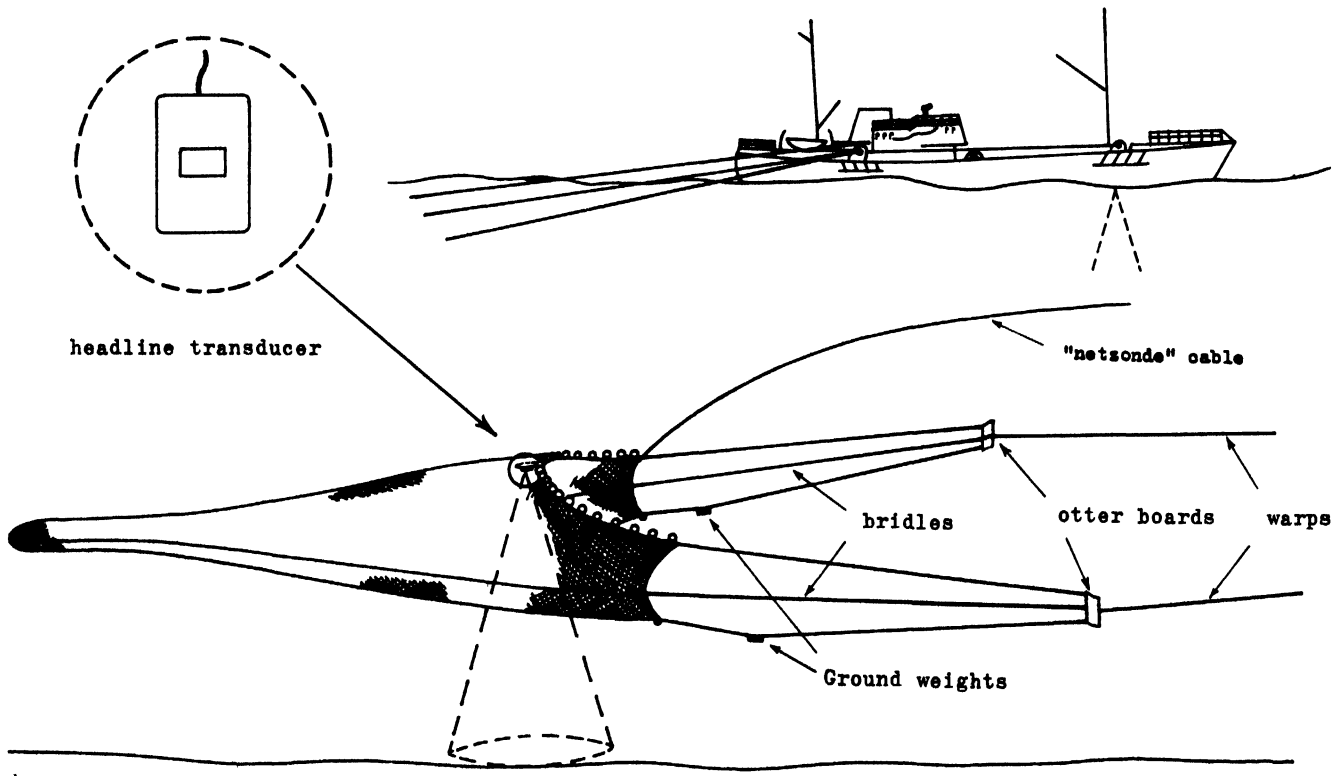

Fig. 1. Schematic view of a midwater trawlgear with two-seam net and Netzsonde.

fishing trials until mid-1962 showed that the catching efficiency of this gear for non-spawning herring was not adequate for commercial operation and very poor indeed in comparison with that of the two-boat midwater trawls which at this time were already to some extent in commercial operation.

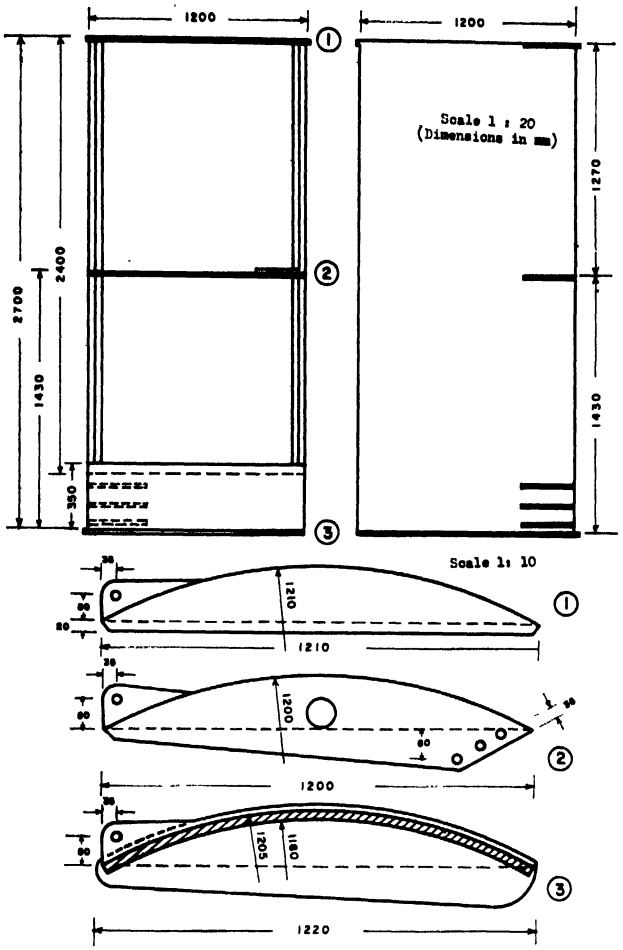

Fig. 2. Dimensional drawing of a Süberkrüb type otter board of 3·2 m² as used in the trials with larger trawlers of up to 1,200 hp.

Observations and experiences collected during these fishing trials indicated that two shortcomings were probably mainly responsible for this inferiority of the one-boat gear, namely (a) insufficient width of the area swept and (b) less suitable design, particularly mesh shape, of the two-seam net. To overcome these shortcomings, the distance between the otter boards had to be increased considerably and the trawlnet design had to be modified or even a new design had to be developed. Interesting details covering these preliminary trials and earlier efforts are available to all interested in the original paper submitted to the Congress and in the reference papers listed at the end of this article.

Effective modifications

After a last comparative fishing test in October 1962 (Table I), drastic modifications were made.

Table 1.—Comparison of herring catches (in baskets of 50 kg each) by experimental one-boat midwater trawler Sägefisch *with pair-trawlers* Everling *and* Dahrendorf: *Skate Hole, in October, 1962.*

Oct.	*Sägefisch* baskets per day	*Sägefisch* per hour towing	*Everling, Dahrendorf* baskets per day	*Everling, Dahrendorf* per hour towing	Catch relation fishing day Sägefisch = 1
7	100	17	425	48	4·3
8	43	4	210	24	4·9
9	170	19	810	105	4·8
10	95	10	550	69	5·8
21	100	23	760	113	7·6
22	20	2	280	25	14·0
23	88	9	390	39	4·4
24	180	21	450	43	2·5
Total:	796		3,875		4·9

Modification of the trawl gear

To increase the distance between the otter boards their size was almost doubled to 6 m² each and the bridles were lengthened to 100 to 150 m. For these larger otter boards the proportions of the Süberkrüb design were retained but the construction was strengthened (Fig. 4).

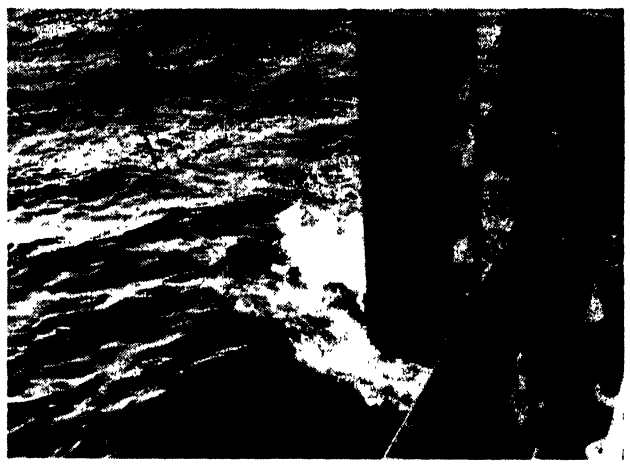

Fig. 4. Süberkrüb otter board of six m² size constructed for the modified one-boat trawlgear, during shooting from a sidetrawler. The bridles are operated with the trawl winch by means of one mutual pennant.

Since this larger size corresponds closely to that of the ordinary flat otter boards of large trawlers, while the weight was even less, no operation difficulties were encountered. The mode of operation of the boards and bridles remained unchanged. For the bridles steel wire of 16 to 18 mm diameter was chosen.

Depending on the type and size of net, the length of the bridles, the warplength and the towing speed, these modifications almost doubled the distance between the otter boards to about 65 to 90 m without unduly stretching the net itself sideways.

In order to improve the catching efficiency of the trawlnets not only a modified two-seam net was designed but also a new four-seam type, adapted for one-boat trawling. (Most of the development work regarding nets was done in close co-operation with the net-making firm H. Engel, Kiel.) For the practical fishing tests a

sidetrawler of 1,250 hp was used, which represents in type and power a good number of trawlers of the German deep-sea trawler fleet (Fig. 5).

Fig. 5. The German deep-sea trawler Johannes Krüss *on which the modified trawlgear was tested. This vessel represents, in regard to type and power, a good number of sidetrawlers in the German trawler fleet.*

A good deal of the midwater trawling for herring in the North Sea and the North-East Atlantic is conducted very near to or even on the bottom, with extremely high-opening nets. In order to reduce the risk of tearing the net when occasionally fishing on the bottom, the front edge of the netting along the footrope was reinforced, the footrope itself served with rope and the front part of the lower net in some of the nets was made of stronger twine.

So far the new two-seam type with 1,000 meshes circumference, shortened wings and modified hanging for more closed mesh shape has not been thoroughly tested. It is therefore still in an experimental stage and a detailed description here appears premature.

Of the four-seam type two sizes were made, one with 1,200 and one with 1,400 meshes circumference (Fig. 6). The two main differences of this type, as compared with the ordinary four-seam nets of the pairtrawlers, are the rectangular (or rather oval) shape of its opening and the slightly protruding lower panel. The rectangular shape with the side panels narrower and shorter than the upper and lower panels was chosen because earlier experience had shown that it is difficult with the one-boat rig to open sufficiently in vertical direction a net with equal panels. This general trawl form, which is well known, e.g., in Japan and the U.S.A., is so far rarely found in Northern Europe. The forward extension of the lower panel is meant to give the net a downward sheering tendency to secure good bottom contact if desired. This feature, together with the in-built additional extension of the lower net by means of special hanging, also makes up for the sag of the lower bridles caused by the heavy ground weights (370 to 430 kg each). It furthermore allows the otter boards to travel above the centre line of the trawlgear and this removes the warps, with their supposedly disadvantageous scaring effect, even more out of the path of the trawl.

The modified trawlgears technically performed very satisfactorily. The main technical characteristics, as were found during the limited number of fishing trials, are compiled in Table II.

Propeller revolutions and speed were taken from the instruments installed on board. Net-depth and opening-height were measured with the Netzsonde and the trawler's echo sounder. The distance between the otter boards was deduced from the spread of the warps in the sliphook. The distance between the wingtips was calculated from the distance between the otter boards considering the length of the bridles and of the net bag up to the front edge of the tunnel.

Since so far only a limited number of measurements could be taken during two trial trips in December 1962 and February/March 1963 to the Norwegian coast (Egersund-Stavanger) and the Icelandic south coast (Skeidarár Deep), the values reported here should not be taken as final. They give, however, a clear enough

Table II

Gear type	Propeller r.p.m.	Speed knots	Warp-length fm	Net depth (headline) m	Opening height m	Distance between otter boards approx. m	Distance between wingtips approx. m
1,400 meshes, 4-seam, bridles 150 m, groundweights 470 kg each	90 to 106 (full)	3·8 to 4·2	200 to 300	110 to 170	20 to 22	70 to 80	24 to 27
Ditto—groundweights 370 kg each ..	90 to 106 (full)	3·3 to 3·9	300	110 to 150	approx. 21	approx. 75	approx. 25
1,200 meshes, 4-seam, bridles 150 m, groundweights 370 kg each	90 to 106 (full)	3·2 to 4·2	150 to 450	90 to 247	17 to 22	85 to 90	25 to 27
Ditto—bridles 100 m..	86 to 106 (full)	3·1 to 4·5	350 to 450	105 to 205	15 to 19	60 to 75	23 to 29
1,000 meshes, 2-seam, bridles 90 m, groundweights 289 kg each	90 to 106 (full)	3·4 to 4·1	300 to 450	106 to 196	17	60 to 65	27 to 29
Ditto—bridles 100m, groundweights 370 kg each	90 to 98	3·4 to 4·0	325 to 350	130 to 135	17 to 18	—	—

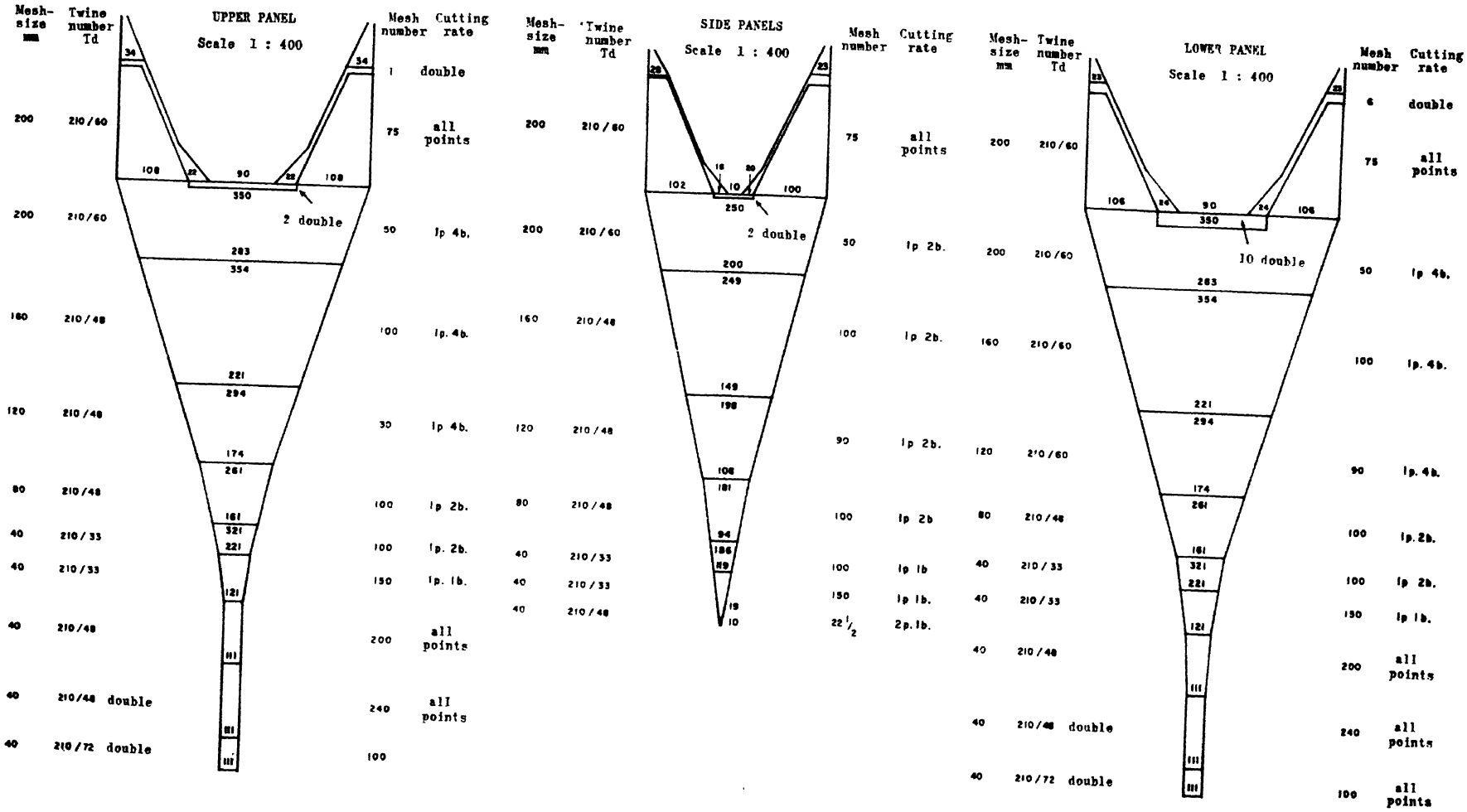

Fig. 6. Combination one-boat net for trawling in midwater and on the bottom, 1,200 mesh circumference, four-seam type.

Table III

Daily midwater trawling catches in baskets (50 kg each) of the one-boat trawler J. Krüss (1,200 hp) versus the catches of two-boat trawlers of different size and power

Date	J.Krüss	Everling and Dahrendorf	Daneker and Schulte	Thiele and Wessels	Minden and Bielefeld	Detmold and Stadthagen	Wind and sea
6 Dec.	390/30 1/	250/5	280/25	300/-	200/-	- - - 2/	changing 2-3
7 "	170/25	160/-	homeward bound	400/-	280/-	- - -	SW 2
8 "	x x x 3/	x x x	- - -	x x x	x x x	- - -	S 7-9
9 "	30/3	30/-	- - -	x x x	x x x	- - -	WNW 5 high swell
10 "	100/10	x x x	- - -	x x x	x x x	- - -	NNW 7
11 "	170/5	180/-	- - -	x x x	x x x	- - -	changing 3-4
12 "	x x x	x x x	- - -	x x x	x x x	- - -	NW 7-10
13 "	30/-	40/-	0 0 0 4/	x x x	2/-	1/- 0 0 0	NW 4-5
14 "	(_ /25)	450/-	575/-	x x x	x x x	120/-	S-W 5-7
15 "	620/-	homeward bound	x x x	0 0 0	(180/80) 5/ (0 0 0)	(30/-) (0 0 0)	NW 6-7
16 "	left out because J.Krüss was in harbour to take salt						
17 "	x x x	- - -	x x x	x x x	x x x	x x x	SO 7-8
18 "	x x x	- - -	x x x	x x x	x x x	x x x	SO 8
19 "	120/-	- - -	x x x	homeward bound	40/-	50/-	SO 2-6
Total:	1630/98	1110/5	855/25	700/-	702/80	201/-	
Catch per day on the grounds	125/8	123/1	122/4	58/-	54/6	34/-	

Everling/Dahrendorf = modern sidetrawlers of similar size and power as J.Krüss

Thiele/Wessels = small combination drifter/trawlers of 300 hp each

Daneker/Schulte, Minden/Bielefeld and Detmold/Stadthagen = large combination drifter/trawlers of 600 hp each

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The figures in front of the dash give the herring catch, the figures behind 1/ the catch of other marketable species, mainly saithe

- - - - = not present on the grounds

x x x = not fishing because of bad weather

0 0 0 = net damage

5/ = catch of one tow with partly damaged net not included

impression of the improvements achieved. As regards the size of the opening, the experimental modified one-boat trawls are now almost equal even to large two-boat trawls (up to 1,600 meshes circumference). The variations of shape and size of the net opening due to speed variations are within acceptable limits. Also in regard to sturdiness the modified gears seem to be satisfactory for commercial operation under reasonably favourable conditions.

Catching efficiency

After some technical trials, which were required for determining the proper rig of the modified one-boat gear, comparative fishing trials were made versus experimental and commercial two-boat trawlers fishing on the same grounds. A first series of such tests was conducted in December 1962 off the Norwegian coast near Egersund where good schools of non-spawning herring were being fished by midwater pairtrawlers of several nationalities. The results are compiled in Table III.

When comparing this table with Table I, a very distinct change in the relation of the one-boat catches to the two-boat catches is quite obvious. While in comparison with the former one-boat trawlgear the pairtrawlers caught in average about five times more, with the new trawl gear the one-boat trawler now caught as much and even more than any of the German pairtrawlers fishing at the same time on the same grounds. These satisfactory results show that the one-boat midwater trawl must not necessarily be inferior to the two-boat gear even for non-spawning herring, and that the modifications made did actually aim in the right direction.

The table shows further that during the trial period fishing suffered a good deal from rough weather and that, according to expectations, the pairtrawlers were more affected by this than the single trawler. This fact is of significance for winter fishing in the North Atlantic. Pairtrawlers usually stop fishing at wind force 5 to 6 while a single trawler can carry on until about wind force 7 to 8. The superiority of single trawlers in this respect is shown in the last line of the table, i.e., "Catch per day on the grounds" where all days were considered during which the vessels fished or could have fished except for the weather.

The results of this first trial period of only 13 days can, naturally, not be taken as final. The total catches also of the pairtrawlers were not too impressive which must be attributed to the poor weather. There are, however, no obvious reasons so far why also under more favourable conditions the one-boat trawler with the new trawl gear should not be able to keep pace with the pairtrawlers as well. The largest catch per tow of the one-boat trawler was 21 tons, and the best daily catch was 31 tons of herring. The saithe caught was of large size and prime quality.

These promising results encouraged the testing of the modified one-boat gear on another non-spawning herring stock, i.e., the winter herring off the Icelandic south coast. The programme of the next trial trip, again with the sidetrawler *J. Krüss*, included therefore a short trial period in this area. Thanks to the generous assistance of the Icelandic colleagues and authorities, good herring concentrations could be spotted without delay outside the national fisheries limits at Skeidarár Deep-Sidugrunn. At this time of the year (February) this herring is fished by Icelandic purse seiners during night when it is near the surface. During the day it migrates downwards and stays even near the bottom.

Because of the very poor weather (the purse seiners could not fish) and some technical trouble, *J. Krüss* could actually fish only for one day, on 24th February, 1963. On this day the modified one-boat gear, with the new large (1,400 mesh circumference), rectangular four-seam trawlnet, was used. The first tow in the morning yielded nine tons and the second tow at noon and early afternoon 23 tons of herring. Due to a misinterpretation of the Netzsonde echogram, the third tow was extended too long in order to clear first the deck from the earlier catch (Fig. 7). Consequently the bulk of the fish, which

Fig. 7. Large catches are taken on board by splitting into bags of about two tons each as usual on sidetrawlers. The photo shows a catch of about 23 tons of non-spawning herring taken with the 1,400 mesh, four-seam net off the Icelandic coast on 24th February, 1963, in a tow of three hours.

was caught in the very beginning of the tow, had died and become very heavy. When hauling this catch, the auxiliary lines (heavy nylon rope) parted and it was only with the greatest difficulty that the net could be hauled until the beginning of the completely filled-up tunnel

came near the surface. Thus at least a good guess could be made, according to which the catch amounted to somewhat more than 20 tons of herring. Unfortunately the net could not withstand the stress of this heavy catch which was held from the mast of the vessel rolling in rather high seas. It parted before splitting could be started and tunnel and codend with the catch were lost.

A catch of about 30 tons in two tows, or even per day, is considered good herring trawling anywhere. Regarding the total catch of this day, together with the 20 tons lost, the catching efficiency of the modified one-boat trawl for this Icelandic herring must be considered as very satisfactory indeed. Although of a preliminary nature, this positive result could become of significance for the German sea fishery and it is hoped that the fishing industry will soon start to take advantage of the new possibilities offered.

Together with herring some cod and redfish were also caught, indicating that the gear may prove to be efficient also for these species.

Conclusions

The preliminary results of the comparative fishing trials off the Norwegian coast and of the fishing trial off the Icelandic south coast appear to indicate that, with the modifications applied, a significant step forward has been achieved towards one-boat midwater trawling as well as for active non-spawning herring in the North Atlantic. Naturally a great deal of further experience will be needed for the adaptation of this fishing technique to other fish stocks and fishing conditions even in this general area.

For spawning herring, which in the North Sea often occurs in very dense schools yielding large and extremely heavy catches, a smaller and much stronger trawlnet will be required. For cod, saithe and eventually redfish, on the other hand, the same trawlnet as for non-spawning herring, only with larger meshed aft belly, tunnel and codend, will probably be suitable. The operation from sterntrawlers with sternramp will require the usual strengthening of the aft net, tunnel and codend. Particularly for large trawlnets, of 1,000 meshes circumference and more, the four-seam type appears to be better suited than the two-seam type.

Not only can four-seam nets be made shorter, but they are also easier to handle because they need only two instead of three bridles at each side. In order to fully utilise the large towing power (2,000 hp and more) of the big, modern sterntrawlers, even bigger nets will be required. In view of the limitation of the length and also the hauling of heavy catches over the sternramp, rather new and unorthodox designs will probably have to be developed for the construction of such large nets of more than 1,600 meshes circumference.

Further modifications of the rigging will for instance be concerned with trawling on, or rather close over, rough bottom. For trawling near the surface, operational means like towing in circles will probably have to be developed in order to tow the net outside the propeller wake which may scatter or disturb the fish schools.

For rational midwater trawling, navigational aids for spot plotting and optimal means for fish detection are of particularly great importance. Echo sounding and echo ranging are actually indispensable for detecting fish schools in advance and also for observing their movements until the net arrives.

With the introduction of other modern techniques new means will, of course, be found for further increasing the catching efficiency of trawling. This includes the possibilities of applying electric fields, optimum relation of towing speed to size and design of the net, improved release of water through the net to decrease towing resistance, attraction and guiding of fish, which are being considered already. Completely new ones will certainly develop in the future.

This paper deals only with some phases of a continuing development during which, however, results of some practical importance have already been achieved. The one-boat midwater trawl design reached so far is already considered suitable for careful application in commercial fishing. Work will be continued to develop this gear into a still better combined midwater and bottom trawlgear suitable for a wide range of fishing conditions, including part of the present conventional bottom trawling. This gear will, however, not attempt to substitute for the conventional bottom trawl, in particular the models for trawling on rough bottom, but rather to make trawling more versatile and thus help to improve the economy by extending the scope of operations.

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Universal One-Boat Midwater and Bottom Trawl

Abstract
During recent years experiments were carried out in Poland to develop a universal one-boat midwater and bottom trawl for the sprat and herring fisheries. The experiments were carried out with the 1,350 hp deep-sea trawler *Miedwie*, using a four-seam trawl of 680 mesh circumference, 220 mm mesh size in the rounding, with 3,050 × 1,340 mm flat trawlboards. The paper gives full details of the gear and the instruments used, as well as the specific results of the experiments which cover the fishing depth of the trawl in relation to warplength and towing speed, its resistance and horizontal and vertical openings. The graphs allow clear interpretation of the results. During the experiments it was found that by increasing the engine revolutions, the trawl could be lifted safely to pass over bottom obstructions seen on the depth recorder.

Chalut a un bateau pour la pêche pélagique et sur le fond]

Résumé
Depuis quelques années des expérimences ont été conduites en Pologne, dans le but de développer un chalut à un bateau pour la pêche pélagique et sur le fond, destiné à la pêche du hareng et de l'esprot. Ces expériences ont été effectuées avec le chalutier hauturier *Miedwie* de 1,350 cv, utilisant un chalut à quatre coutures, de 680 mailles de circonférence, en mailles de 220 mm, avec des panneaux ordinaires mesurant 3,050 × 1,340 mm. La communication donne les détails de la construction des engins et instruments de mesure employés aussi bien que les résultats obtenus et traite de la relation entre la longueur des funes et la vitesse de touage d'une part, la profondeur d'opération, la résistance et l'ouverture horizontale et verticale d'autre part. Les graphiques permettent l'interprétation claire des résultats obtenus. Au cours de ces expériences on a remarqué qu'en accélérant la vitesse des machines, on pouvait facilement lever le chalut au-dessus des obstacles observés sur l'écho sondeur.

Embarcación universal para la pesca con artes pelagicos y de fondo

Extracto
En los últimos años se han realizado experimentos en Polonia para encontrar una embarcación que pueda emplearse indistintamente para pescar espadín y arenque en el fondo y entre dos aguas. Los experimentos se realizaron con el arrastrero de altura *Miedwie*, de 1,350 hp, empleando un arte de cuatro costuras, de 680 mallas de circunferencia, mallas de 220 mm, y puertas planas de 3,050 × 3,340 mm. El autor da detalles completos del material y de los instrumentos empleados, así como de los resultados específicos de los experimentos, que comprenden la profundidad de pesca del arte con relación a la longitud del cable y velocidad de remolque, su resistencia y las aberturas horizontal y vertical. Las gráficas permiten interpretar claramente los resultados. Se observó durante los experimentos que aumentando las revoluciones del motor el arte se levantaba y pasaba por encima de obstáculos del fondo indicados en el registrador de la profundidad.

by
S. Okonski

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POLAND'S first experiments of midwater trawls were conducted on the sprat schools in the Baltic Sea in 1959, during which two-boat midwater trawls were used. It was then observed that the swimming speed of sprat allowed them to be caught by one-boat midwater trawls operated by cutters. So trials were made with one-boat trawls of synthetic fibres equipped with the ordinary flat otter boards to operate in midwater.

These proving successful the experiments were extended to the bigger vessels so that by 1960 the research vessel *Birkut* (33 m in length) caught 250 barrels (bbl) of herring during midwater trawling on Faren Deep grounds in the North Sea. Subsequently, plans were made for conducting such a fishery with a supertrawler. The trawler used was the *Miedwie*, 1,350 hp, and all measuring equipment was prepared by the technologists of the Sea Fisheries Institute and commercial fisheries companies. The objectives were to investigate the behaviour of the nets and the possibilities of applying ordinary flat trawlboards to midwater operations, as well as to bottom fishing, with this type of vessel.

Although other types of boards have better hydrodynamical characteristics, the flat rectangular trawlboards were used on purpose to avoid difficulties in introducing the new method in commercial fisheries. It is well known that fishermen are often unwilling to accept radical changes, whereas a not too different rig can be readily accepted. The gear was fully designed, constructed and assembled ashore to avoid any major work or changes on board ship. However, some small problems were encountered during the experimental trip, but they were solved by the technologists.

The gear

Full specifications of the net are provided in Fig. 1. All mesh sizes are given for stretched mesh and lengths in metres. The wings and front part of the body are made of polyamide (nylon type fibre) double twine of 1·8 mm diam, while the rest of the body is constructed of single twine, same diameter. The whole net is made up of four identical panels, one of which is seen in Fig. 1. Bosom corners of each panel have a wedge piece to even out strain.

The headline has 55 spherical aluminium floats of 200 mm diam attached at every 40 cm in the bosom, every 50 cm at the quarters and every 60 cm in the wings. The footrope construction was very light, with a total of 30 kg chain. The chain was divided into short lengths; six pieces were attached to the bosom of the footrope, two of them at the extremities of the quarter wedges and one piece in the middle of the wings. At the tip of each bottom wing, a weight of 50 to 60 kg was attached by 60 cm long strops (Fig. 2).

For pulling up the codend, the net was equipped with two porklines, one attached to the codend becket while the second was attached to the middle of the body.

Both lines were of synthetic fibre of 14 mm diam. The net had two quarter ropes of 55 m length attached at the belly quarters and led through the upper quarters.

The net was operated with upper and lower legs which

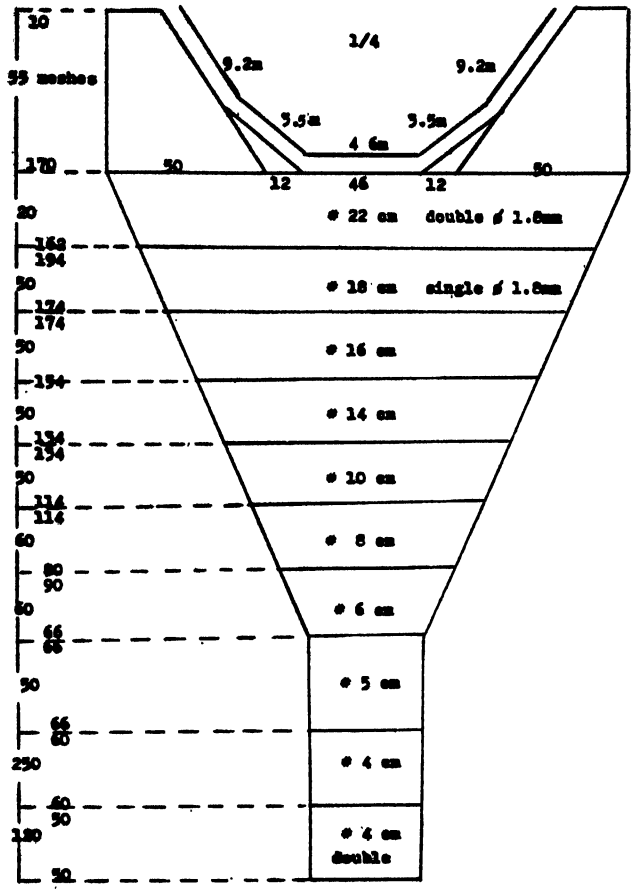


Fig. 1. Detail of trawl construction (one panel).

differed in length by 2·5 m, the upper legs being 82·5 m each and the lower legs 80 m. All legs were made of 12 mm diam steel wire, although in some cases the lower legs were replaced by thicker combination rope of the type used for the bridles.

The otter boards

The boards were of the normal flat oblong type of 3,050 mm × 1,340 mm, weighing approximately 900 kg each, and were specially fitted for midwater trawling by means of two sets of bridles instead of the usual single bridles at the back of the board (Fig. 3). The angle of attack of the boards had been calculated for bottom trawling and the length of the strops differed to ensure that the boards took up a stable position during operations in midwater, so that the upper strops were 2·1 m and 3·6 m, while the lower strops were 2·25 m and 3·75 m, attached as shown in Fig. 3.

The experiments

The measuring instruments used during the experiments

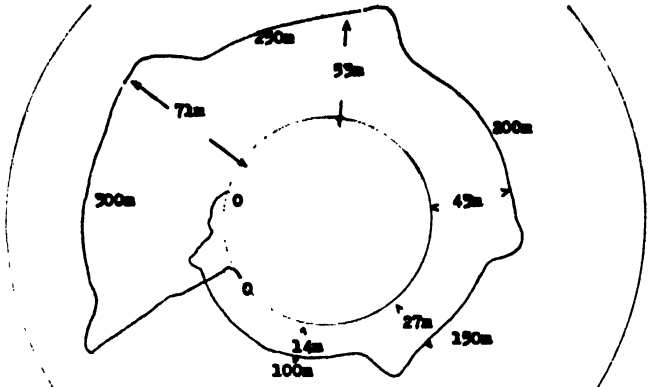


Fig. 4a Headline depth at various warplengths (190 r.p.m.)

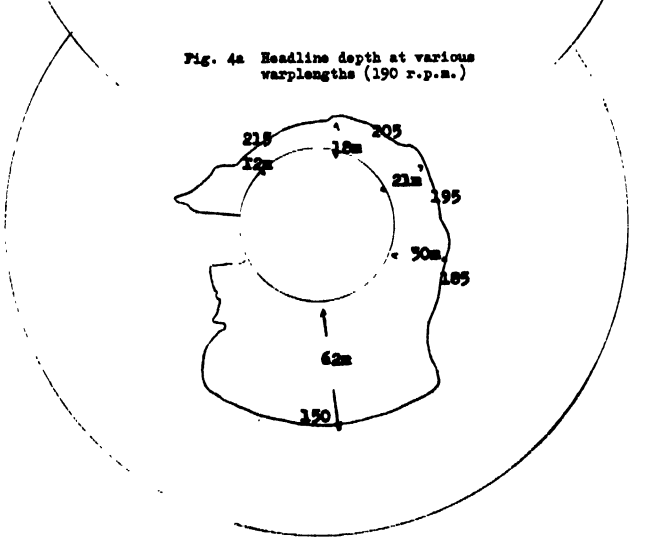


Fig. 4b Headline depth at various propeller speeds (at 150 m length of warps)

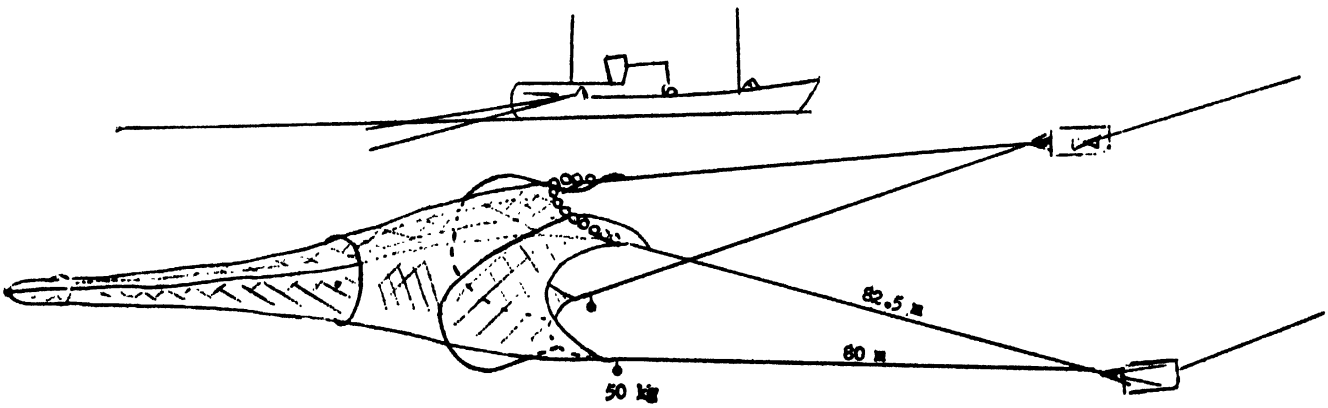


Fig. 2. General arrangement of "Universal" trawl. Symbolic hauling trawler indicated on top.

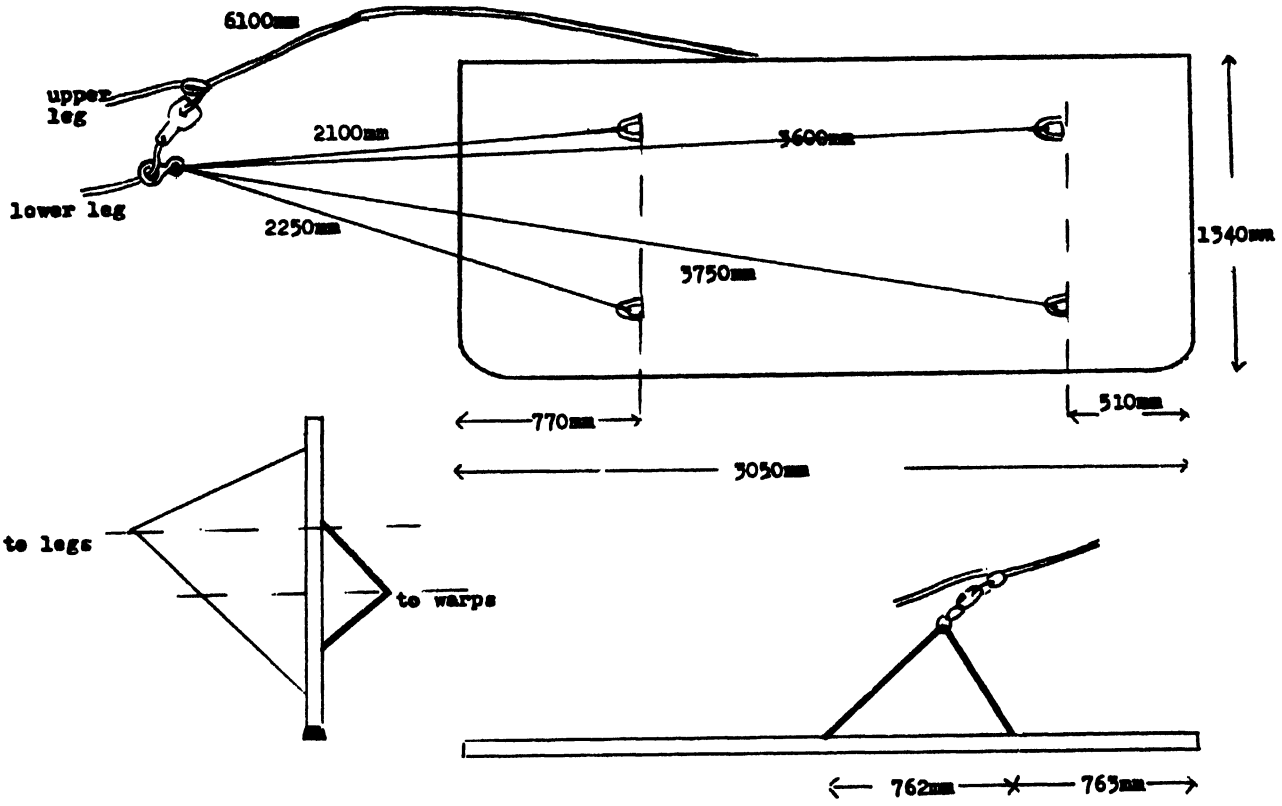


Fig. 3. Details of trawlboard rig.

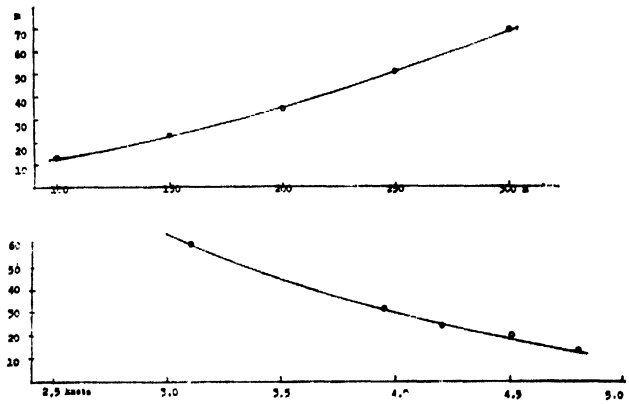
comprised:

(a) A sal log.
(b) Two dynamometers with a range of 0-15 tons for measuring warp tension.
(c) A bathygraph with a range of 0-120 m for measuring operational depth of the trawl.
(d) Differential bathygraph with a range of 0-20 m for measuring the vertical opening of the net.
(e) Wind gauge.
(f) A tachometer for measuring the propeller speed.
(g) An anglemeter for measuring the angle of the warps at stern.

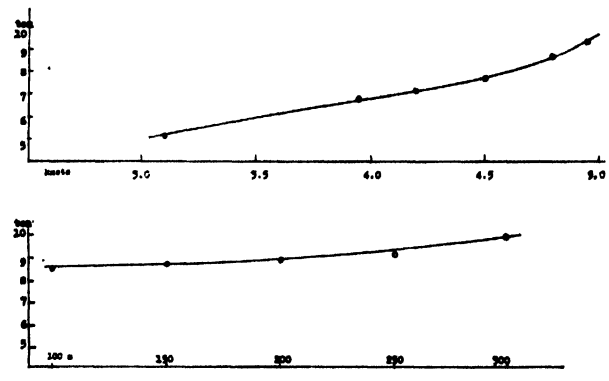
During the experimental hauls, measurements were made to ascertain the shape of the trawl in action whilst towing at different speeds and with different lengths of warp. The data obtained during these trials were worked out to averages, which are presented in the graphs and illustrations given in Figs. 4 to 11.

Fig. 4a shows the graph of the headline depth obtained during the trials in which different warp lengths were used at constant engine revolutions. In Fig. 5a this information is plotted as a curve and, as can be seen, the relation between the warplength and the trawl depth is not linear at constant speed.

Fig. 4b shows the graph of the headline depth obtained when changing the towing speed while keeping the warplength constant. The values are plotted in Fig. 5b and the curve shows that the change in headline depth, due to change of speed, is not constant and is greater at low towing speed than at high towing speed.



Figs. 5a and b (on tow) (a) Relation of headline depth to warplength at constant speed; (b) Relation of headline depth to towing speed (150 m warplength).



Figs. 6a and b (a) Relation of warp tension to towing speed for 150 m warplength; (b) Relation of warp tension to warplength at constant speed.

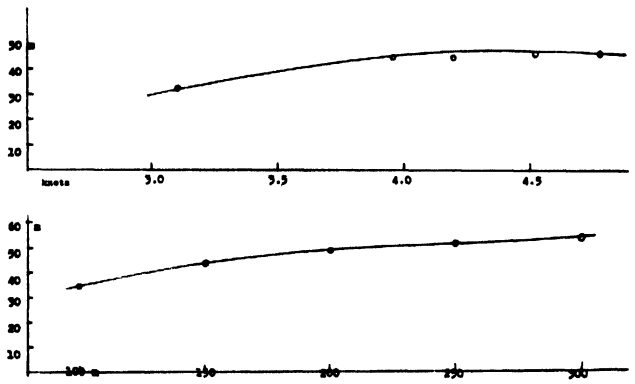
Trawl resistance in relation to towing speed and warp length

The warp tensions obtained during several hauls are shown in Fig. 6. The total tension at five knots was about 10 tons. Whereas the load to speed ratio increases rapidly at higher towing speeds, the increase in load as more warp is veered out at constant speed is almost linear. The amount of warp to be veered out to allow the gear to operate one metre deeper differs according to the length of warp already veered or, respectively, the depth at which the gear is operating. It was found that, at constant engine r.p.m., to allow the net to sink one metre deeper it required:

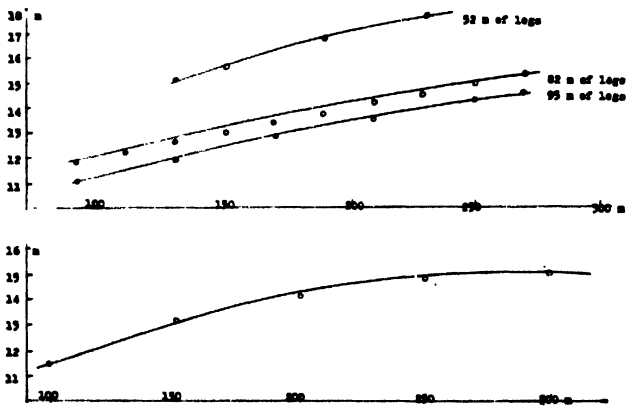
7·8 m	more warp	when fishing	with 100 m	warp out
6·5 m	,,	,,	150 m	,,
5·9 m	,,	,,	200 m	,,
5·0 m	,,	,,	250 m	,,
4·3 m	,,	,,	300 m	,,

The above values are, of course, only valid for the gear used, so that even a change in the rig-up of the trawl will result in a different ratio.

As shown in Figs. 7 and 8, the distance between the otter boards depends on the speed of towing and the length of warps. Legs of 52 m, 80 m, and 95 m were tested and, within this range, the length of legs did not affect much the distance between the boards. On the other hand, the leg length has great influence on the horizontal opening of the net. Longer legs give smaller horizontal net opening. From the purely technological point of view (leaving out biological considerations), 60 m was found to be the optimum length of legs for this type of midwater trawl.



Figs. 7a and b (top) (a) Relation of horizontal opening to towing speed (150 m warplength); (b) Relation of horizontal opening to warplength (constant towing speed).



Figs. 8a and b (a) Effect of leg length on horizontal opening in relation to warplength; (b) Average horizontal opening in relation to warplength.

Headline height

The headline height of the trawls was measured by differential bathygraphs constructed by S. Okonski and J. Zaucha. A typical graph from this instrument is shown in Fig. 9, one of which gives the headline height variation

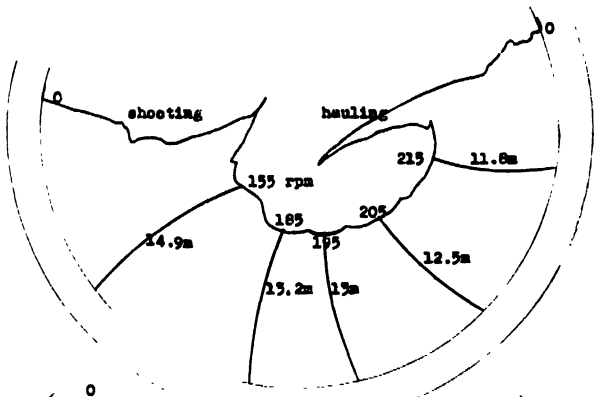


Fig. 9a Headline height in relation to towing speed at constant warplength

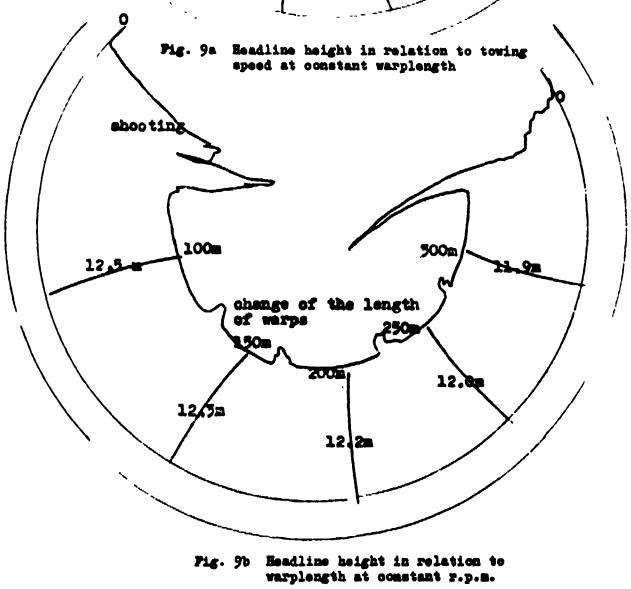
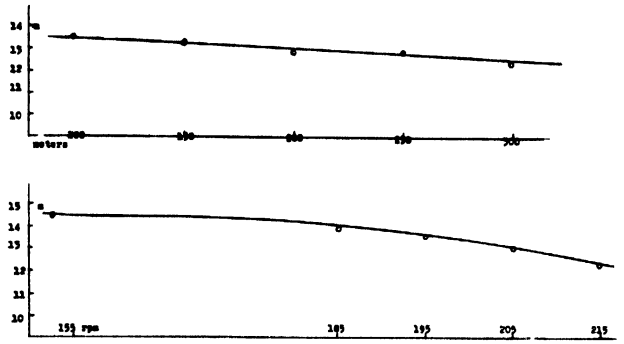


Fig. 9b Headline height in relation to warplength at constant r.p.m.

in relation to towing speed while the other shows the headline variation in relation to warplength. The information contained in the graphs has been plotted as a curve in Fig. 10, which clearly shows that the towing speed has much greater effect on the headline height than the warplength. At 3 knots the opening-height was 14·4 m but at 5 knots it was 11·3 m.

Taking into account the very light rigging and the overall dimensions of the trawl used, the average headline height of 12 m at a speed of four knots would appear to be very satisfactory. This headline height could, however, be increased by a heavier rigging and the use of hydrodynamical lifting power. Furthermore, a bigger



Figs. 10a and b (top) (a) Headline height in relation to warplength at constant r.p.m.; (b) Headline height in relation to towing speed at 150 m warplength.

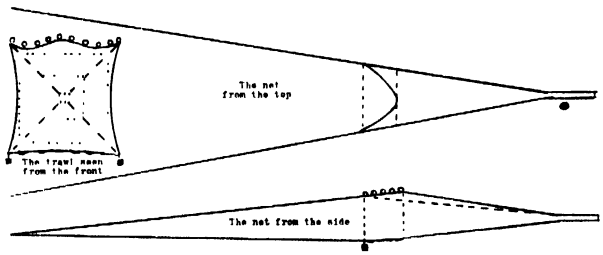


Fig. 11 The shape of the trawl during towing.

net could be used as the gear was small for the engine power of the vessel.

Area of the trawlmouth

Using the above data on headline height and horizontal opening, the catanary of the headline and the footrope can be calculated and the area of the netmouth is then obtained for different conditions of towing speed and warplength.

Keeping the engine at constant revolutions, the area of the netmouth was found to change as follows for the different warplengths:

Warplength m	Area at wingtips m^2	Area at bosom m^2
100	140	117
150	150	132
200	169	141
250	176	145
300	178	147

When the warplength is kept constant with an increasing towing speed, the area of the trawlmouth was found to be maximum at 185 r.p.m.

at r.p.m.	Area at wingtips m^2	Area at bosom m^2
150	158	131
185	183	151
195	181	149
205	176	146
215	170	140

Fig. 11 shows the general configuration of the trawl in action. The experiments generally conform that the pelagic trawl is a delicately balanced fishing gear which required close co-ordination of the many factors influencing its shape and operation.

Fig. 12a. Shooting. Arrangement of leg strops on otter board.

Fig. 12b. Releasing the quarter rope during hauling (note sinkers on lower leg).

Operation techniques

The operation of the "Universal" trawl is similar to that of the ordinary bottom trawls. In hauling and shooting the main difference lies in the absence of bridles and danlenos and, on the other hand, the use of long legs which, being connected through Kelly eyes and pennants, are led straight onto the winch drums.

The gear can be shot while the vessel is stopped or steaming round, in the same manner as the ordinary bottom gear. The wire of the upper and lower legs should preferably be of right and left twist respectively, to avoid their twisting together during the hauling. In the rig used, the lower leg was stoppered through the Kelly eye, whereas the upper leg was connected to the same stopper outside the Kelly eye (Figs. 3 and 12 a). The addition of two leg-strops at the back of the board improved the stability of their performance, especially during poor weather. For operation on the shallower Sandettie grounds in the English Channel, the legs were shortened to 52 m.

Fishing results

The 1962 herring season on English Channel grounds was very poor and this gave an opportunity to investigate the comportment of the gear to other than midwater towing conditions. The purpose was to assess the possibility of operating on the bottom as well as near the surface. Three days were devoted to this work and during some of the tows, though there had been no trace on the echo sounder, up to 10 bbl of herring were caught.

The distance of the footrope from the bottom could be regulated very accurately. With the footrope chain arranged as previously described, the footrope functioned at 80 cm above the bottom; when 10 kg of chain was added to the wings this distance was reduced to 30 cm; with 10 kg more chain in the bosom the net touched bottom.

During these experiments the possibilities of lifting the gear over obstacles was also investigated and it was found that this could be done easily by appropriate increase of the engine revolutions. Fig. 13 gives the echo-recording of one occasion when the echo sounder showed 10 to 12 m rocks straight ahead. The dotted lines show the track followed by the gear when the engine speed was increased. About 1·8 min after increasing the speed, the net had risen four m; 3·2 min later it had risen 11 m and after a further 3·7 min it was 18 m above the bottom, passing clear of the rocks.

The experiments have shown that this gear can be operated easily at any depth. There remain, however, some small problems, one of which is the provision of cheap and efficient net telemeters for commercial fishing operators.

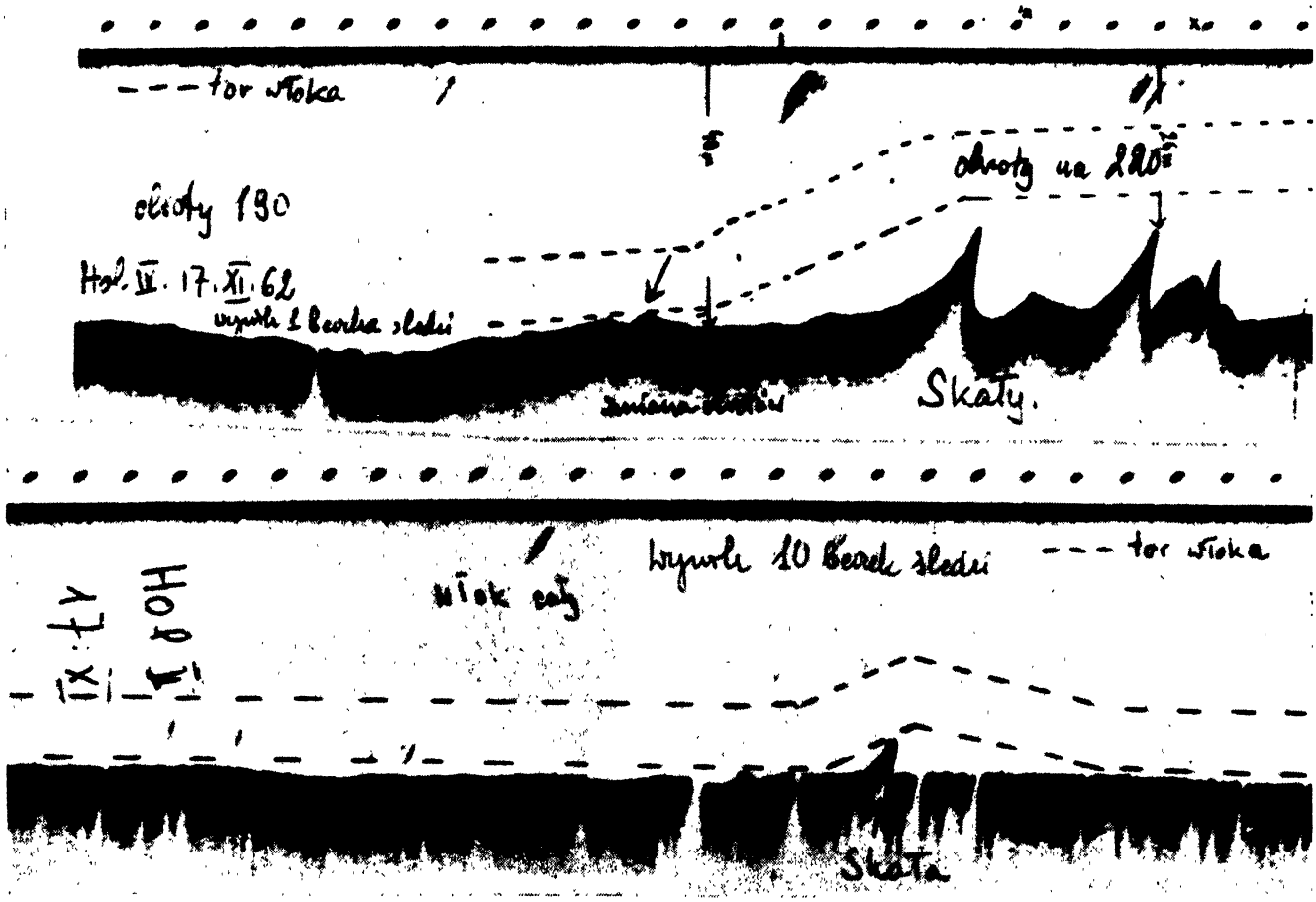


Fig. 13. Echogram of the gear being lifted over obstacles.

Two-Boat Midwater Trawling for Herring with Bigger Boats

Abstract
In 1961 and 1962, the German trials with two-boat midwater trawling for herring in the North Sea were extended to larger vessels of the lugger type (300 tons, 40 m long, 450 to 600 hp) and big trawlers (400 to 650 tons, 43 m to 53 m long, 600 to 1,250 hp). The experiments have shown that the German luggers can adopt two-boat midwater trawling for herring on a commercial scale without serious technical difficulties. Since good manoeuvrability is essential when the boats have to come closer together during shooting and hauling, controllable pitch propeller, diesel-electric drive and/or active rudder are the more desirable the larger the vessels are. Even big long-distance side-trawlers can operate a two-boat midwater trawl if good manoeuverability is secured by one of the above means. The operation costs of such large vessels are, however, so high that two-boat trawling would only be profitable under exceedingly good fishing conditions. The German combined luggers can operate at moderate costs. Consequently, they are adopting two-boat midwater trawling for herring at an increasing rate and the economic results have so far been highly satisfactory. In the beginning the larger pair of trawlers used four seam trawlnets of a similar type as are common for smaller vessels in northern Europe, but of appropriate size, i.e., 1,400 to 1,600 meshes (mesh size 200 mm stretched) circumference in the mouth giving an opening height of 14 to 20 m. The trend now is, however, to adopt a trawl-type with "rectangular" opening and modified rigging.

Chalutage pelagique a deux bateaux pour grands chalutiers

Résumé
En 1961 et 1962 les essais allemands pour développer le chalutage pélagique à deux bateaux pour le hareng, dans la Mer du Nord, ont été étendus à des bateaux plus grands du type lougre, de 300 tonnes, 40 mètres de long et de 450 à 600 cv et aussi à des chalutiers hauturiers (de 400 à 650 tonnes, 43 à 53 mètres de long, 600 à 1,250 cv). Les expériences ont montré que les lougres allemands s'adaptaient au chalutage pélagique à deux bateaux, à une échelle commerciale, sans difficultés techniques sérieuses. Une hélice à pas variable, un entraînement électrique Diesel, un gouvernail actif sont des facteurs désirables pour les grands chalutiers car une grande manoeuvrabilité est essentielle surtout quand les bateaux se rapprochent pour échanger les lignes. Même les bateaux de pêche lointaine opérant par le côté peuvent utiliser les chaluts pélagiques à deux bateaux s'ils obtiennent une bonne manoeuvrabilité par les moyens décrits ci-dessus. Cependant le coût d'opération de ces grands bateaux est si élevé que le chalutage à deux bateaux ne peut être profitable que sous des conditions extrêmement favorables, tandis que les frais des opérations des lougres allemands sont plus modérés. C'est pourquoi les lougres allemands ont adopté rapidement le chalutage à deux bateaux et les résultats ont été très satisfaisants. Au premier, les grands chalutiers "pareja" utilisaient des chaluts à quatre coutures du même type que ceux utilisés par les petits chalutiers dans le Nord de l'Europe, mais d'une grandeur appropriée, c'est à dire de 1,400 à 1,600 mailles (de 200 mm, maille étirée) de circonference à l'ouverture ce qui donne une ouverture verticale de 14 à 20 m. Neanmoins la tendance aujourd'hui est pour un chalut avec une ouverture rectangulaire et de montage modifié.

Empleo de parejas mayores para la pesca al arrastre pelagica del arenque

Extracto
En 1961 y 1962 los ensayos practicados por los alemanes con artes de arrastre pelágicos remolcados por las embarcaciones que pescan arenque en el Mar del Norte, se ampliaron de manera que comprendiesen otras mayores del tipo llamado "lugger" (300 ton., 40 m de eslora, motores de 450 a 600 hp) y arrastreros grandes (de 400 a 650 ton, 43 a 53 m de eslora y motores de 600 a 1,250 hp). Los experimentos han demostrado que, sin graves dificultades técnicas, las parejas de "lugger" alemanes pueden pescar arenque con artes pelágicos en escala industrial. Como la maniobrabilidad es esencial cuando los barcos tienen que acercarse para largar y virar la red, cuanto más grandes son más conviene el empleo de propulsores de paso variable, transmisiones diesel eléctricas y timones activos, o uno de los dos últimos. Incluso los arrastreros de altura que pescan por el costado pueden emplear el arte pelágico remolcado en pareja si se les da buena maniobrabilidad por uno de los medios citados. Sin embargo, la explotación de barcos tan grandes es tan costosa que la pesca en pareja sólo es provechosa en condiciones excepcionalmente buenas. La explotación de los "lugger" combinados alemanes es relativamente modesta, por lo que cada vez hay más parejas de ellos dedicados a la pesca del arenque con artes pelágicos, habiendo obtenido hasta ahora resultados muy satisfactorios. Originalmente las parejas mayores empleaban artes de cuatro relingas de un tipo parecido a acquellos utilizados para las más pequenas buques del norte de Europa que pescan con artes, pero de una dimension conveniente, as decir de 1,400 a 1,600 mallas (de 200 mm cuando están estiradas) de circunferencia en la abertura, lo que de una abertura vertical de 14 a 20 metros. Hoy dia, pero, la tendencia es de emplear las artes con una abertura rectangular y aparejo modificado.

by
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AN extensive and very successful herring fishery with two-boat midwater trawls has developed in the North Sea. Until a few years ago only smaller boats—cutters of 60 to 100 tons—were engaged in this fishery. These cutters are easily manageable and have relatively powerful engines (up to 600 hp).

The good commercial results of the cutters suggested that bigger vessels would also be suitable, so two-boat midwater trawling trials were carried out by the Institut für Netz- und Materialforschung of the Federal Republic of Germany. The main problem in two-boat trawling is the passing of lines from one boat to the other during shooting and hauling. It was found that the suitability of vessels for two-boat trawling depends more on manoeuvrability than on size. Accordingly boats fitted with controllable pitch propeller or diesel-electric drive proved best suited because propeller performance, including reversing, can be controlled quickly and efficiently from the wheelhouse. Boats with an active rudder are also relatively easy to manoeuvre and are consequently suitable too. Big trawlers without such equipment are less suitable for two-boat trawling.

Four-seam trawlnets are mostly used in two-boat midwater trawling. The German luggers (600 hp) now use nets of 1,400 meshes circumference at the mouth (mesh size 200 mm stretched—Figs. 1 and 3). For the first trials with large German trawlers (of about 1,000 hp) a trawlnet of 1,600 meshes in circumference (mesh size also 200 mm stretched) was designed and gave very good results (Fig. 2). The opening height of the lugger nets ranges between 14 and 18 m, and that of the trawler net between 16 and 20 m.

Because of the very big catches taken occasionally,

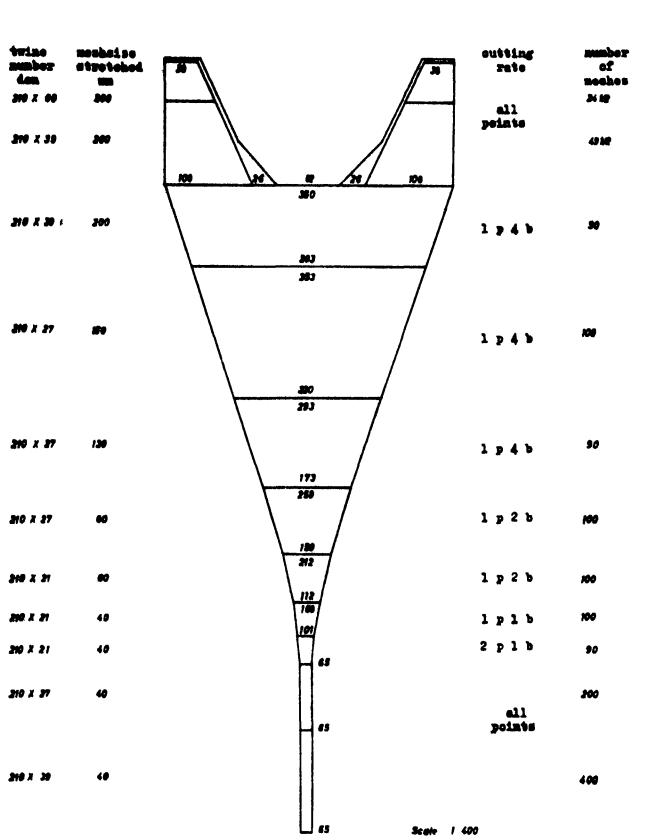

Fig. 1. Structure of one panel of a four-seam two-boat midwater trawlnet for luggers (about 600 hp each). The net consists of four such panels.

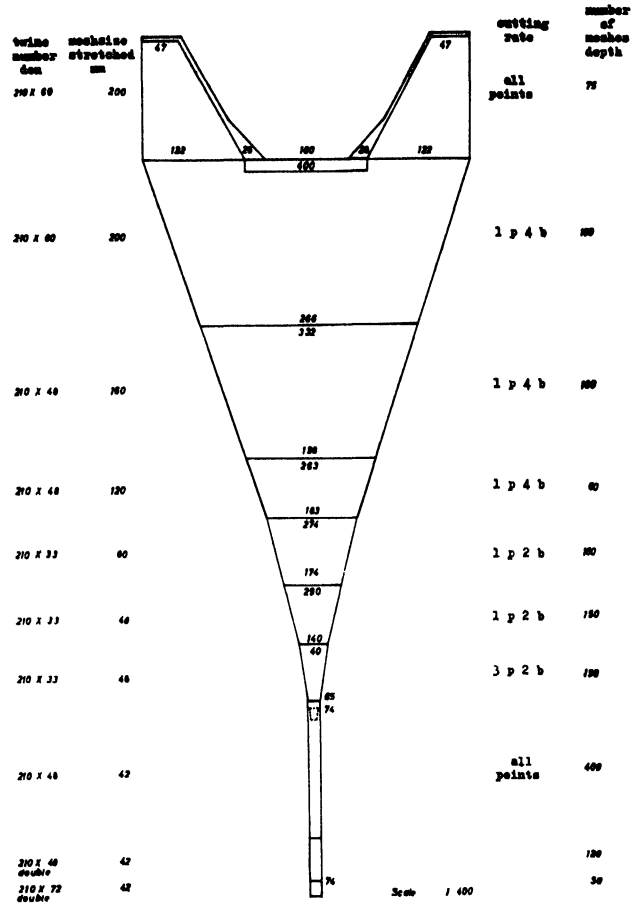

Fig. 2. Structure of one panel of a four-seam two-boat midwater trawlnet for larger side trawlers (about 1,000 hp each). The net consists of four such panels.

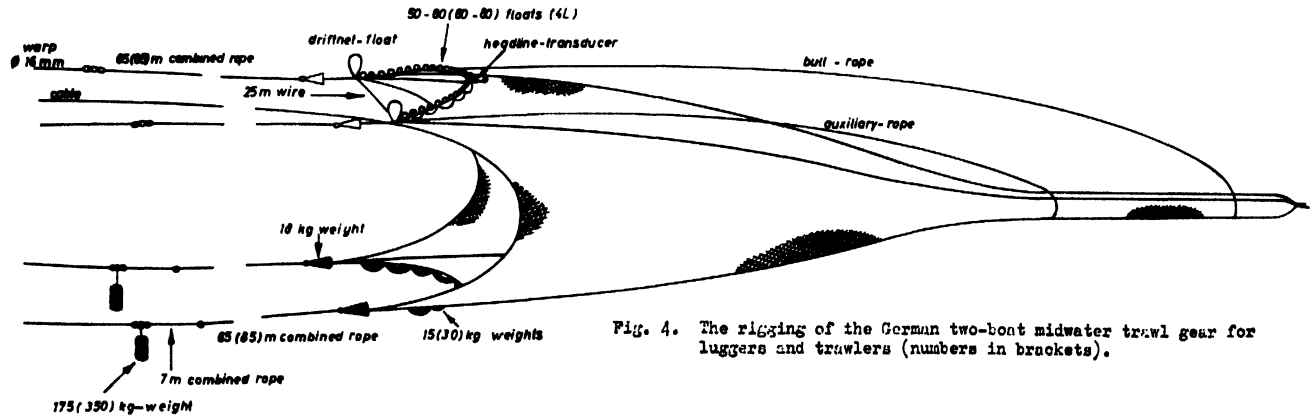

Fig. 4. The rigging of the German two-boat midwater trawl gear for luggers and trawlers (numbers in brackets).

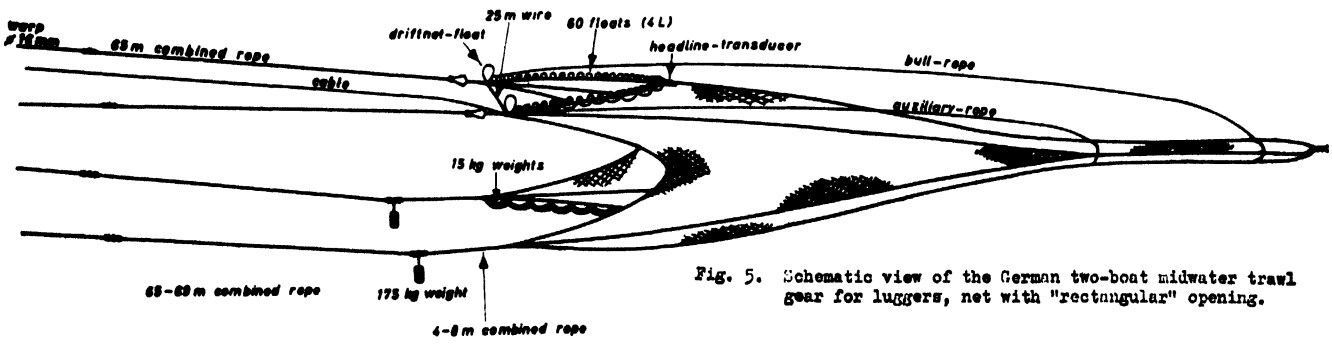

Fig. 5. Schematic view of the German two-boat midwater trawl gear for luggers, net with "rectangular" opening.

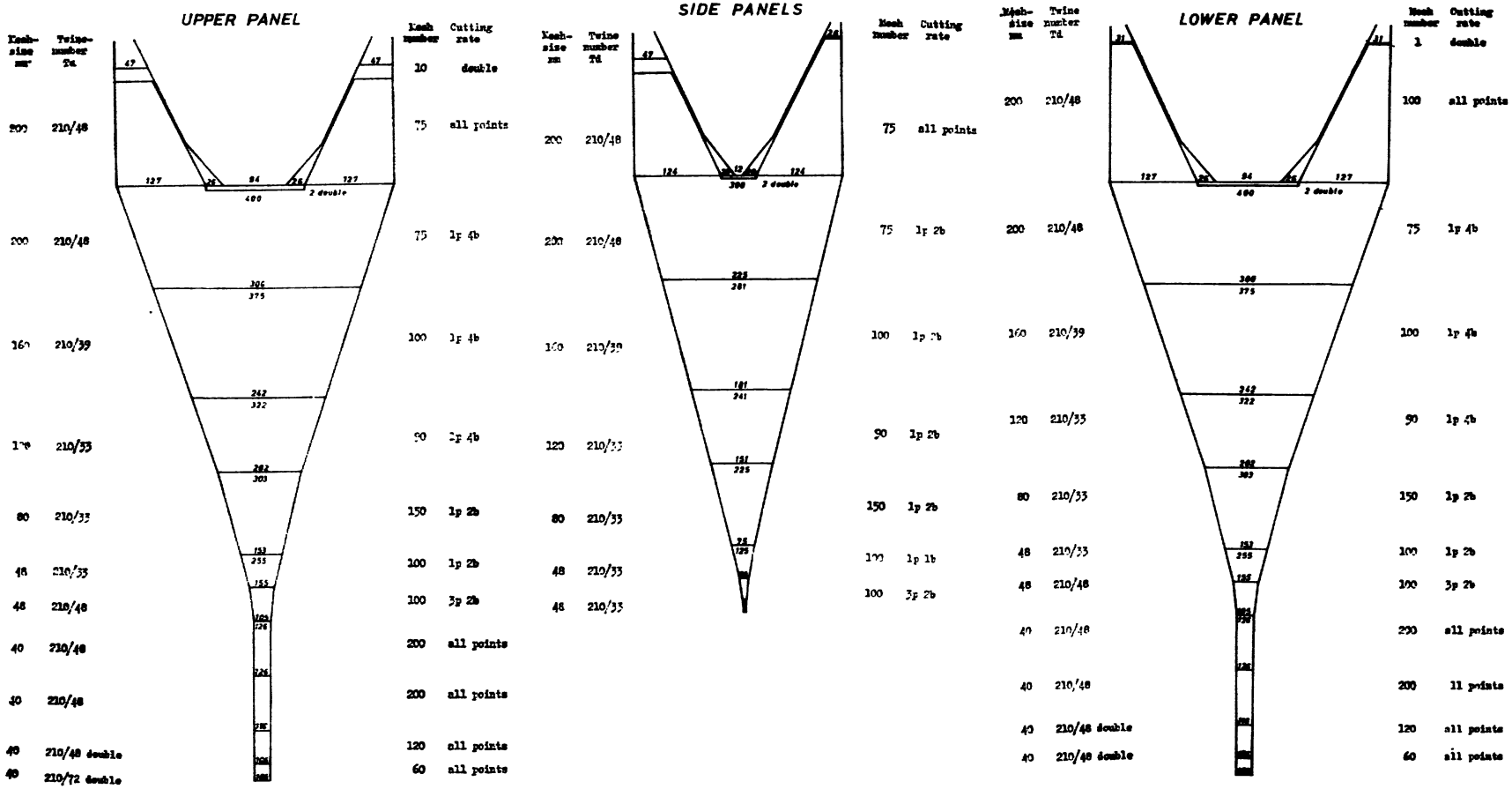

Fig. 3. Structure of a four-seam two-boat midwater trawlnet with "rectangular" opening for luggers (about 600 hp each)

net material of high breaking strength must be used, particularly since the netting twine should be as thin as possible in order to provide optimum water flow through the netting and minimum frightening wake in front of and in the mouth of the trawl. Nylon or 'Perlon' (polyamide 6) continuous multifilament twines were mainly used. During the extensive herring fishing trials in the North Sea the twine strengths given in Figs. 1, 2 and 3 were found adequate. Finer netting is not recommended because it does not withstand the stress of bad weather and/or large catches. Sufficient elasticity of the net material is of great importance for absorbing shock loads and unavoidable distortions of the net.

Arrangement of the legs and weights used in the first trials is shown in Fig. 4. Of the figures given, the first one refers to the lugger gear and the second one, in brackets, to the trawler gear. According to their size the trawlers use longer legs than luggers do. In this way the handing over of the legs from one boat to the other during shooting and hauling is simplified. The 25 mm wire between the upper wingtips is very important because it prevents damage to the trawlnet in case the distance between the two boats becomes too wide during shooting and hauling. For modified rigging of the two-boat midwater trawl with rectangular opening see Fig. 5. Here the big weights are fastened near the lower wingtips rather than at the juncture of the lower wings and legs.

The warps normally used by these vessels in bottom trawling are considered too heavy for midwater trawling, causing a small opening-height of the net mouth. Therefore the German luggers and trawlers are using warps of 16 mm diameter for midwater trawling instead of the normal 19 to 24 mm warps.

As a net depth telemeter, all German luggers and trawlers use the so-called "netzsonde" so that the depth of the net is recorded continuously during fishing, as well as the opening-height of the net and the fish passing through the net mouth, etc. Moreover, it indicates the behaviour and distribution of those fish so that valuable conclusions can be drawn for the most efficient tactics of operation. (Mohr this Congress.) With the "netzsonde" much bigger catches are obtained on average.

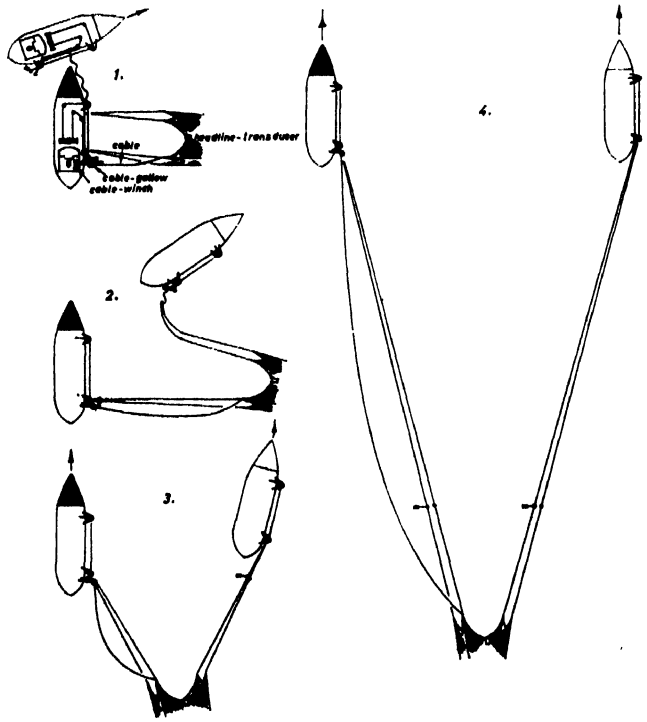

Fig. 6. Method of shooting the net from the "netzsonde" boat.

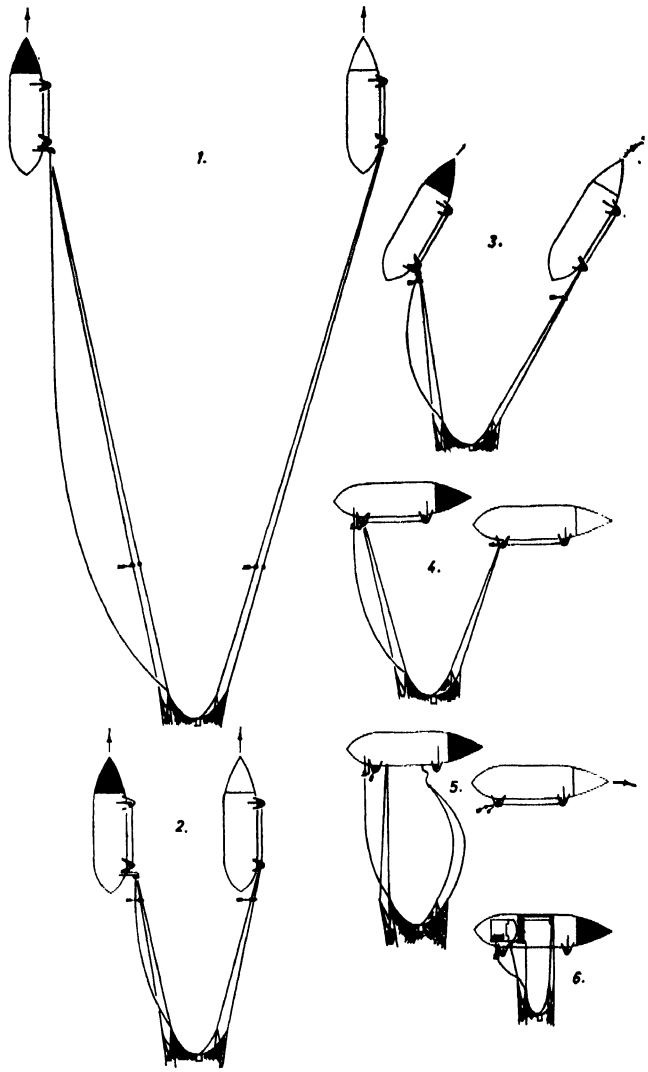

Fig. 7. Method of hauling the net on the "netzsonde" boat.

In the two-boat trawling normally only one boat is equipped with a complete "netzsonde" unit. The other has only a separate headline transducer with about 120 m of cable attached to her trawlnet. If the net of this boat is shot, this cable is connected with the main cable and the electronic unit on board of the "netzsonde" boat during shooting (Fig. 6). In this way the one "netzsonde" echo recorder unit can be used with the nets of either partner at will.

In two-boat midwater trawling two methods are used for shooting and hauling (Figs. 6-9). When the "netzsonde" boat is shooting (and hauling), the method 1 shown in Figs. 6-7 is applied. When the partner boat is shooting her net, method 2 (Figs. 8-9) is used. In

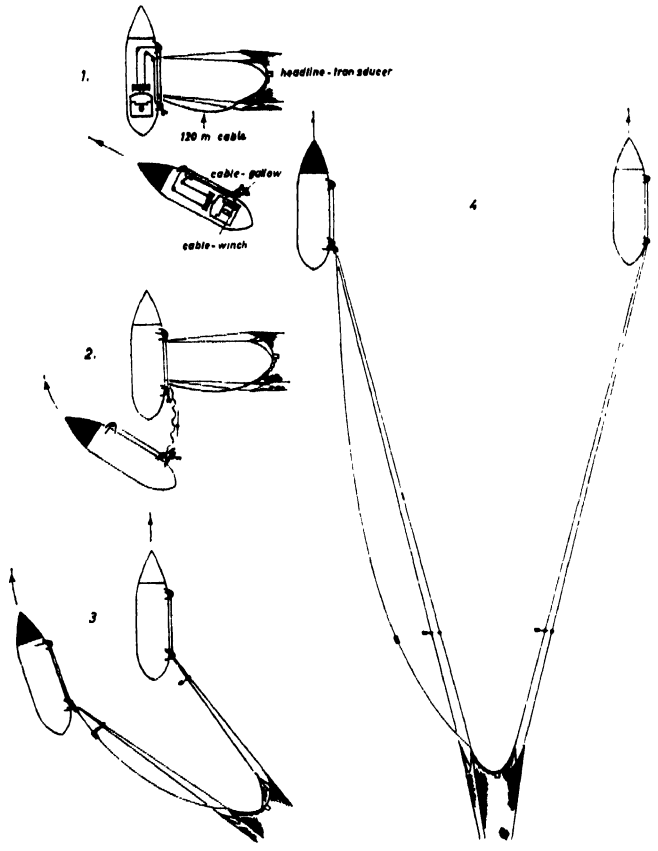

Fig. 8. Method of shooting the net from the partner boat. The cable of the headline transducer is connected with the main cable on the "netzsonde" boat by means of a special plug.

this way the "netzsonde" boat is always on the same (port) side of the partner boat when towing. This arrangement is necessary because roller and winch equipment for handling the cable is directed to the starboard side of the "netzsonde" boat.

The depth of the trawl is regulated by variations of towing speed and/or the length of warps. This is the same for one-boat and two-boat trawling. To change the net depth within about 10 to 15 m, it is normally sufficient to alter only the speed. If greater changes of net depth are needed then the warp length has to be altered.

In two-boat trawling it is difficult to change course quickly. When fishing deep with long warps, about 45 min would be needed to turn to the opposite course. Such turns can be achieved much faster by hauling in the warps up to 50 fm, turning the boats round in a small circle and veering the warps again. In this way only about 15 min are needed.

German luggers are taking up commercial two-boat midwater trawling for herring in the North Sea at an increasing rate. The economic results have so far been highly satisfactory. However, it is still an open question whether a similar development will materialise in the case of the larger side trawlers. For economic reasons, and because only a few of these vessels have the required manoeuvrability it seems likely that if they should take up commercial midwater trawling at all, they may use the one-boat technique.

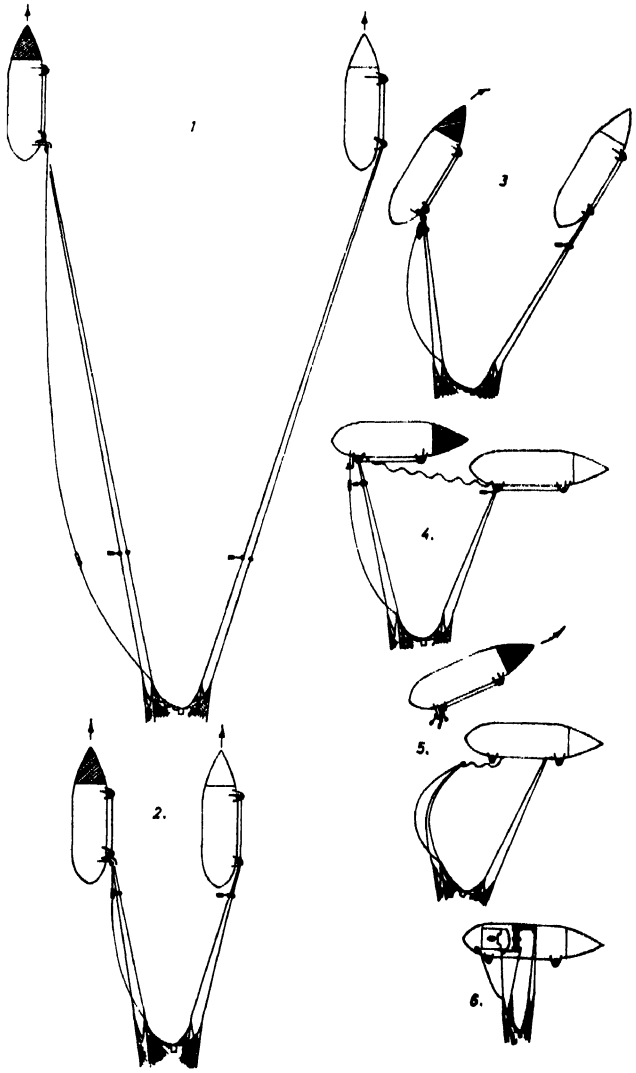

Fig. 9. Method of hauling the net on the partner boat.

Development of the Cobb Pelagic Trawl

A Progress Report

Abstract
A large single boat pelagic trawl utilizing hydrofoil otter boards is under development by the Bureau of Commercial Fisheries Exploratory Fishing and Gear Research Base in Seattle, Washington. The general configuration of the huge gear is based on the theory that a large net travelling at relatively low speed through midwater or on the surface (Fig. 1) would be more effective in capturing large, active fish than a small net towed at high speed. Construction details have primarily resulted from direct observation of experimental nets in action by SCUBA-equipped staff members. These observations have allowed a series of modifications to be performed, resulting in attainment of a favourable ratio of net size to horsepower requirements. A mouth opening of approximately 7,200 sq. ft. and a towing speed of 2.5 kn. using 350 hp. has been accomplished.

Résumé
Actuellement, au Centre de la Pêche Explorative et de la Recherche des Engins de Pêche est dévelloppé, par le Bureau de Pêche Commerciale des Etats-Unis, à Seattle (Washington), un grand chalut pélagique à un seul navire, équipé de plateaux hydrodynamiques. La configuration générale de cet engin immense est fondée sur l'hypothèse qu'un grand chalut remorqué, soit entre deux eaux, soit près de la surface (Fig. 1), à une vitesse relativement faible, serait plus apte à capturer les grands poissons très actifs qu'un petit chalut remorqué à une grande vitesse. Les détails de sa construction résultent principalement d'observations sous-marines de l'engin en fonction effectuées par des employés du Centre, équipés de scaphandres autonomes.

Ces observations ont permis d'apporter toute une série de modifications qui ont abouti à une relation plus favourable entre les dimensions du chalut et la puissance du moteur. C'est ainsi que l'on a augmenté l'ouverture du chalut jusqu'à près de 700 mètres carrés pour une vitesse de touage de 2.5 noeuds et une force motrice de 350 c.v.

Extracto
Un arte de grandes dimensiones para la pesca al arrastre pelágica, dotado de puertas hidrodinámicas y para ser remolcado por una sola embarcación se construye en la Base de Investigaciones de Material de Pesca y de Pesca Exploratoria de la Oficina de Pesca Industrial, Seattle, Wáshington. La forma general del enorme arte se basa en la teoría de que una red grande que se desplace a poca velocided relativa entre dos aguas o en la superficie (Fig. 1) pesca más peces grandes, activos, que una pequeña remolcada a mucha velocidad. Los detalles de la construcción se deben principalmente a observaciones directas de artes experimentales por investigadores equipados con escafandras autónomas. Las observaciones han permitido realizar una serie de modificaciones que han dado por resultado la obtenión de una relación favorable de dimensiones de la red a necesidades de fuerza motriz. Se ha logrado una abertura de red de cerca de 7.200 pies cuadrados a la velocidad de remolque de 2.5 nudos con un motor de 350 hp.

by
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Research Bureau of Commercial Fisheries, Seattle

COMMERCIAL fishermen and marine scientists have in the past often considered improvements in the techniques of harvesting stocks of fish known to inhabit midwater. Their interest in mid-depth fishing was accelerated with the introduction of echo sounding machines which, in addition to registering the depth of water under the vessel, indicated marine life at intermediate depths (Alverson and Powell, 1955). In recent years a variety of mid-depth fishing trawls have been used experimentally in attempts to efficiently harvest pelagic fishes (Parrish, 1959).

During early 1961 a programme of one-boat midwater trawl development was undertaken by the Bureau of Commercial Fisheries, Exploratory Fishing and Gear Research Base, in co-operation with the Bureau's Biological Laboratory at Seattle, Washington. A multi-purpose gear was envisioned which would be both commercially acceptable by the fishing industry and useful as a pelagic fish sampling device.

Design concepts

The initial concept of a gear capable of this dual operation was that it should be of sufficient size to utilize the maximum horsepower available (350 hp) in the Service's research vessel *John N. Cobb*. Prior experiments aboard the *John N. Cobb* with a British Columbia herring trawl (Barraclough and Johnson, 1955) the Larsson Phantom

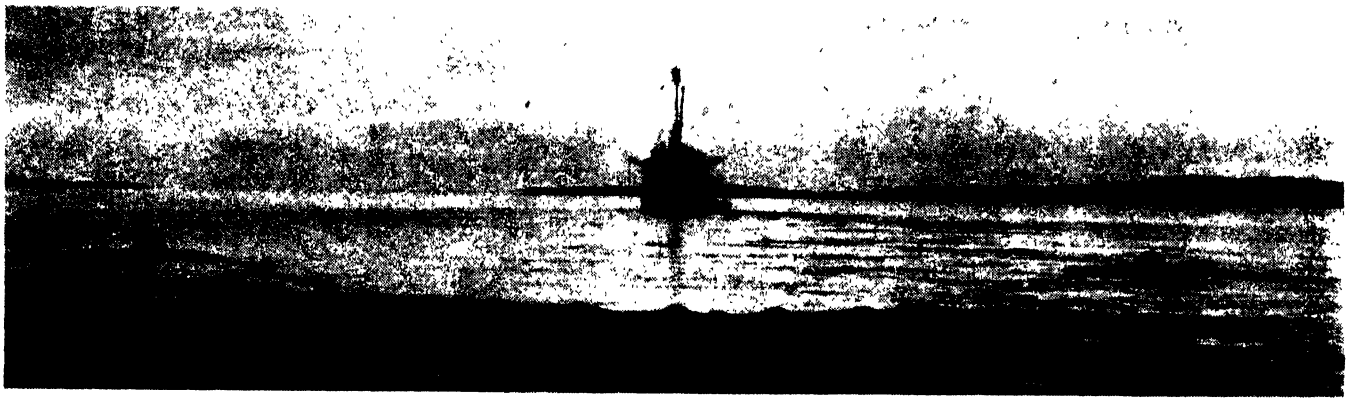
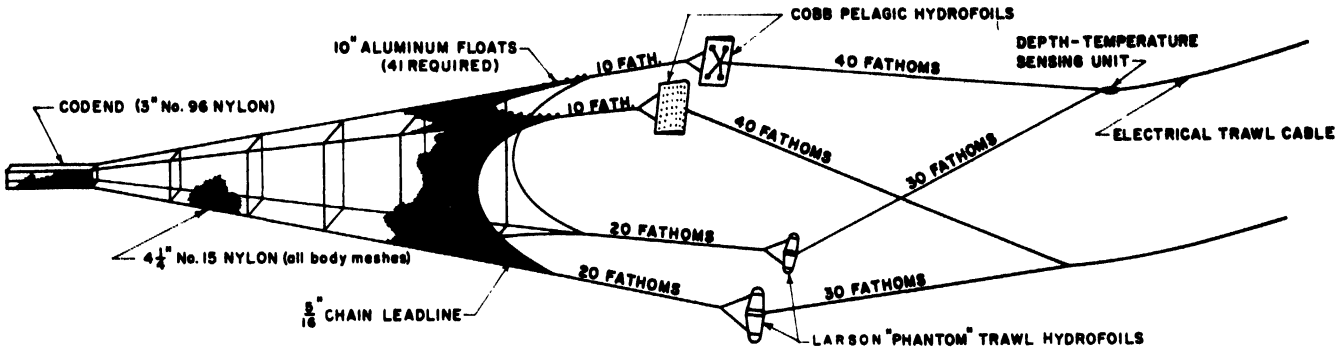


Fig. 1. Float line of giant Cobb Pelagic Trawl skims surface 185 fm. aft of the research vessel John N. Cobb.



COBB PELAGIC TRAWL (1961)

Fig. 2. Otter board and bridle arrangement used to open the Cobb Pelagic Trawl

trawl (Larsson, 1952), and other conventional midwater trawls designed and constructed by the Bureau of Commercial Fisheries indicated that fish could be captured at towing speeds less than 2 kn. Moreover, directing observations (using SCUBA) and televised observations (Sand, 1959) of the reaction of fish to the approach of trawls show that most large pelagic fishes are capable of swimming speeds in excess of that necessary to avoid capture. Thus the capturing gear should be of sufficient size to entrap the fish before it becomes aware of the net. It was reasoned that a four-door otter board and bridle system (Fig 2) would be more effective in opening the mouth of the net than a conventional dual otter board system requiring unusually long bridles and unusually large doors.

Gear design experiments

In 1960 a partially constructed experimental two-boat surface trawl was purchased from a California tuna vessel owner-operator who had abandoned pelagic

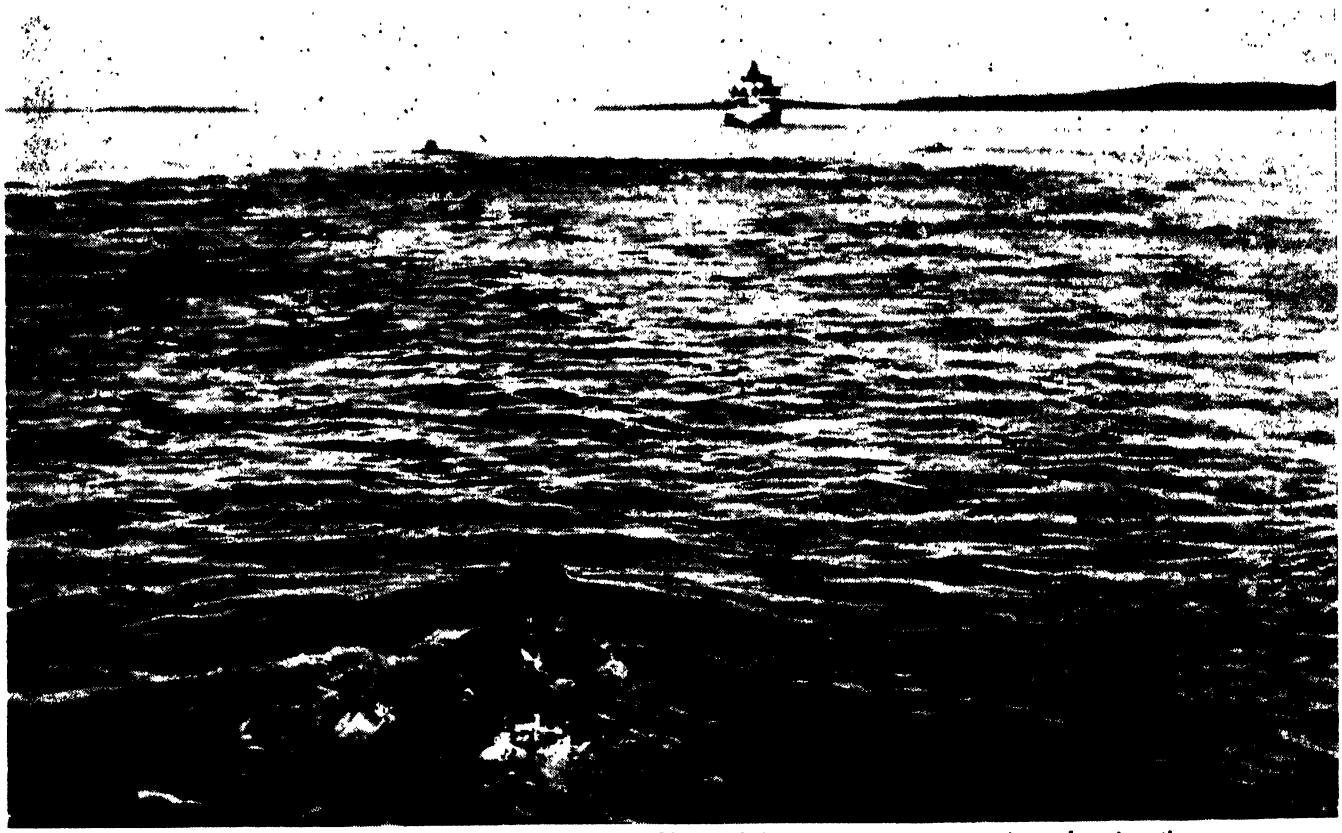


Fig. 3. SCUBA-equipped divers mounted on manoeuvrable sea sled prepare to examine experimental net in action.

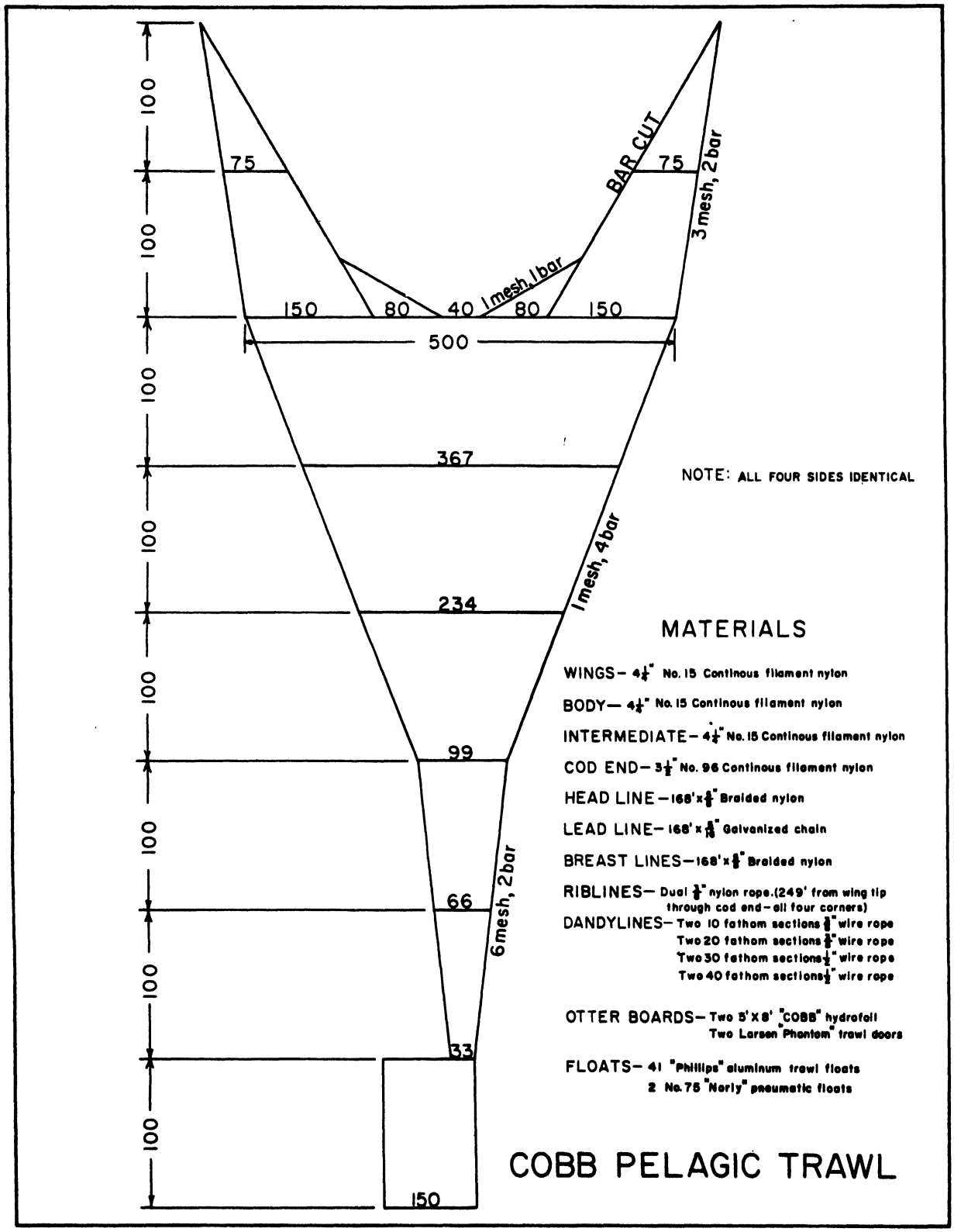


Fig. 4. Cobb Pelagic Trawl

trawling experiments. In early 1961 assembly of the huge net to its original specifications was completed. During this same period a four-door otter board system was designed and constructed to provide maximum opening and single-boat operation of the gear. A desired performance characteristic of high lift at low speeds of midwater-otter boards appeared to be similar to aircraft wing sections used in the 1930's. Therefore, two experimental hydrofoil otter boards constructed of plywood and timbers were fitted with an appropriate bridle system to operate in conjunction with two patented "Phantom" trawl otter boards. The gear was then observed in action by SCUBA-equipped divers using a sea sled (Fig 3).

The net was found to have several defects which required extensive modifications to correct. The principal observed defect was excessive slack or "bagging" of webbing around the mouth of the net, apparently caused by the box-shaped wingless design of the net. Breastlines and footrope were found describing near semi-circular parabolic curves when viewed perpendicular to the longitudinal axis of the net. No provision for displacement of these sections from a straight line had been made. Subsequent to these findings, the net was disassembled, redesigned and rebuilt with long tapering wings, hung in along the corner riblines 13.4 per cent. Underwater observation of the redesigned net, named the Cobb Pelagic Trawl (Fig 4), revealed a considerable improvement in performance. Most of the slack webbing had been eliminated, resulting in a more satisfactory ratio of net opening to number of meshes across the mouth. The immediate visible effect was a greater mouth opening and improvement of individual mesh openings which ranged in configuration from 60° diamonds to 90° squares. A more equalized distribution of load throughout the net was observed. Correction of an insufficient vertical opening was achieved by installation of $\frac{1}{16}$ in. chain for the lead line and increasing the number of floats on the headrope.

Otter boards

The attempt to provide horizontal spread of the net through use of large hydrofoil otter doors in conjunction with "Phantom" travel otter boards has been successful. A measured opening of 80 ft has been achieved during trials. The plywood doors which measured 8 ft 2 in in height and 5 ft in length, have a blunt nose and proportionately thick chord section (Fig 5). It was necessary to provide sufficient holes on the back (curved) side of the doors to allow rapid flooding and spilling of water from each of the hollow compartments during setting and retrieving operations (Fig 6). A metal shoe was placed on the lower side of each door to provide weight for stabilization and to allow use of the doors in future bottom trawling or near bottom pelagic trawling experiments. Observed performance characteristics of the doors showed them to be very stable, even when sets were made in cross currents. No tendency for the doors to cross was observed. Since both sides of the doors were covered with a plywood skin, no deflection vanes were

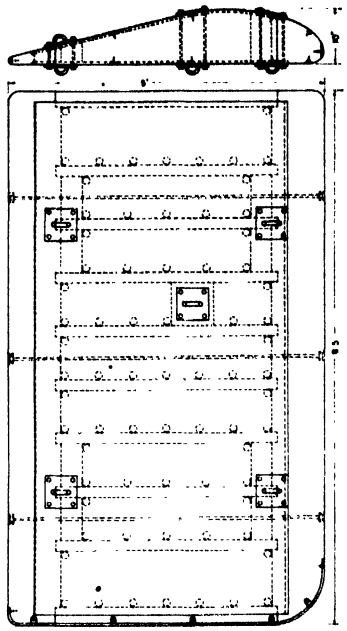


Fig. 5. Prototype Cobb Pelagic Otter Board (1961)

needed to ensure proper setting. The doors responded effectually to changes in bridle chain lengths which allowed manipulation of angle of attack for maximum spread. Changes in differential lengths of the trace chains at the rear of the doors provided control of rising or diving in the water. This function was useful during tests of the gear rigged to fish on the surface.

Four-door hookup

Use of Larsson "Phantom" trawl doors in conjunction with the larger plywood doors presented initial problems in hookup. The Larsson doors were later found easier to set and retrieve when placed ahead of the plywood

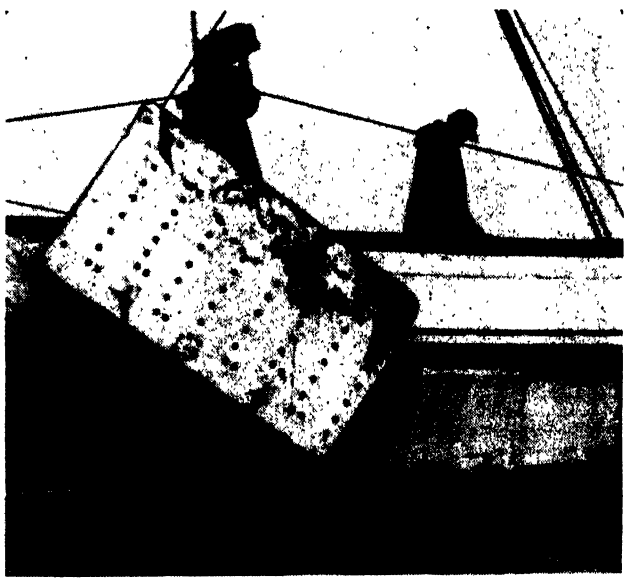


Fig. 6. Numerous holes (drilled on curved side only) allow rapid flooding and drainage of inner compartments.

doors. Positioning of the larger doors on the upper bridle section and the Larsson doors on the lower bridle section was found desirable since a part of the function of the upper doors in a four-door arrangement is to counteract their own weight and diving effect of the lower doors, thereby stabilizing the depth of the net.

Use of the gear on the surface after use at depths of 150 to 200 fathoms resulted in a change in the attitude of the plywood doors due to their becoming water logged. Prior to mid-depth tows surface tows could be made using 150 fathoms of cable. Following the mid-depth tows, attempted surface tows using more than 25 fathoms of cable resulted in the net sinking beneath the surface. This observation indicated the advisability of using all metal doors which would maintain a constant attitude at all depths.

Modifications in 1962

In early 1962 the Cobb pelagic trawl underwent further modifications in design to improve operational characteristics. The redesigned net, "Cobb Pelagic Trawl—Mark II" (Fig 7) incorporated the following changes:

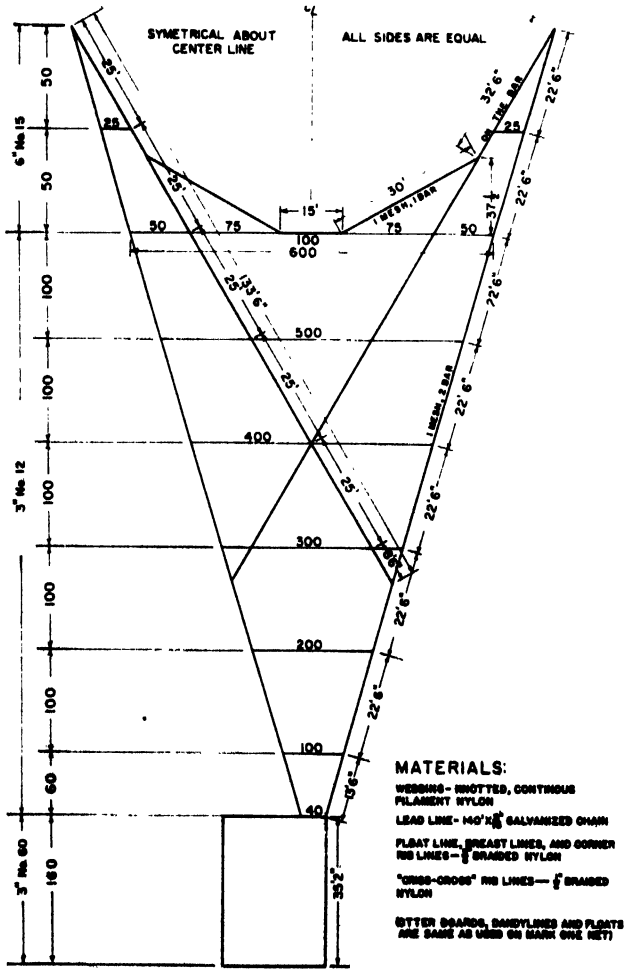


Fig. 7. Cobb Pelagic Trawl—Mark II

(a) Reduction of mesh size to 3 in (stretched measure) in the body of the net to eliminate at least part of a serious gilling problem (Fig 8) encountered with the original model.

(b) Reduction of length and horizontal size of the net to compensate for increased drag of smaller meshes.

(c) Elimination of multiple tapers along the corners by using a straight line taper from wing tip to bag.

(d) Installation of "criss-cross" riblines for better equalization of strain during instances involving unequal lengths of towing warp.

Fig. 8. Mackerel and dogfish shark, gilled in intermediate section of trawl, suggest reduction in size of meshes.

(e) Use of 6 in webbing in the wing sections to reduce drag.

Aluminium hydrofoil otter boards

Redesign of the large plywood hydrofoils to all aluminium construction was also completed early in 1962. The new doors (Fig 9) utilized the same basic characteristics of air foil cross section with vertical size (8 ft) larger than the fore-aft dimension (5 ft). To develop vertical stability, 72 3½ in glass ball floats were placed in the

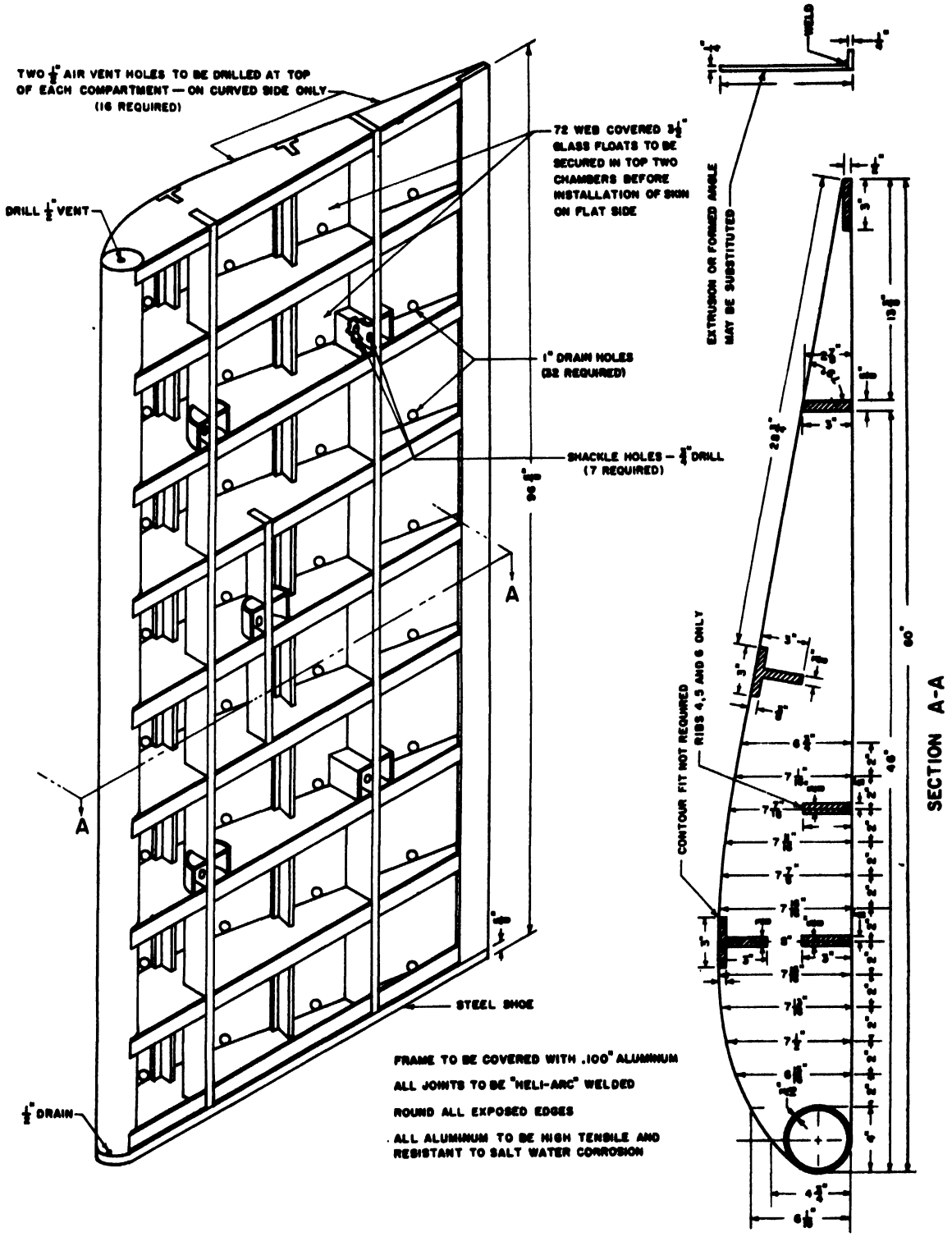


Fig. 9. Cobb Pelagic Otter Board (1962)

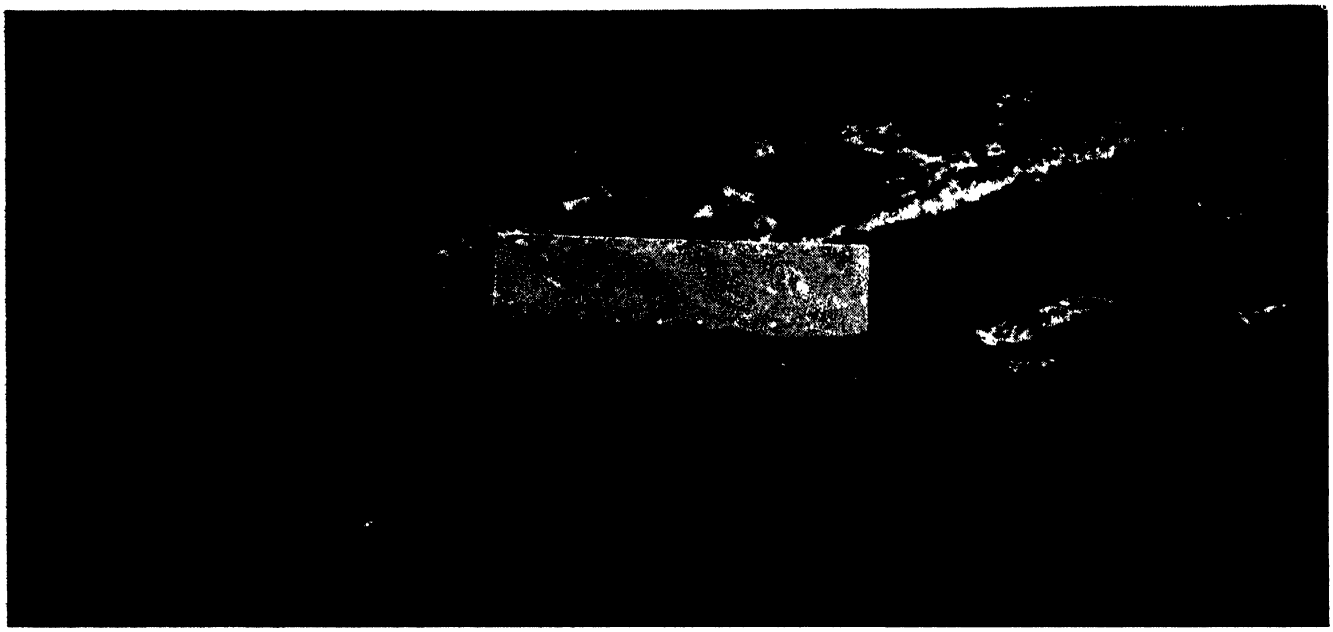


Fig. 10 New aluminium otter board as seen from afterdeck of the John N. Cobb.

upper two rib chambers of each door. Each glass ball was covered with heavy webbing and packed in fibreglass to prevent damage during use of the doors.

Underwater observations 1962

Following construction of a new Mark II—Cobb Pelagic Trawl and modification of existing gear to Mark II design in early 1962, the trawl, equipped with aluminium hydrofoils and Larsson "Phantom" trawl doors, was again observed in action by SCUBA-equipped divers. With the exception of moderately excess strain noted in the wing tips, the net appeared to be fully expanded and exhibited the characteristics of a semi-elastic body being inflated by an internal force similar to the manner in which air inflates an airport wind sock. This condition extended throughout the net from the wings to the "bitter end" of the codend. A near circular cross section shape was noted. Meshes from the wings through the codend were examined by sight and feel to gain knowledge of strain distribution. The amount of strain on individual meshes in all but the forward sections of the wings was found to be small, even in areas adjacent to the riblines. The slight increase in strain in wing meshes was attributed to a greater amount of stretch in ribline in this area, due to the concentration of total load at the four wing tips. A further improvement in net performance is expected when corner riblines are rehung using an incremental hang-in ranging from approximately 15 per cent at the wing tips to approximately 10% at the codend junction. (See note 1 - p. 248)

Observations of the new aluminium hydrofoils from shipboard (Fig 10) and below water showed them to be very stable and responsive to adjustments in bridle and trace chains. Through manipulation of chain linkage it was possible to tow the net on the surface 185 fathoms behind the vessel.

Measurements

Direct measurement of horizontal opening was secured through two auxiliary launches between which a tight line was suspended in the air over wing-tip mounted buoys —shown in Fig 1.

Vertical opening measurements were secured by sea-sled mounted SCUBA divers descending alongside the net and observing differences in depth gauge readings.

Average towing speed of 2.5 kn was arrived at by use of radar and Loran to establish start and end positions of a series of a trial drags, usually of one hour duration.

Depth assessments of the net during experiments at sea trials were secured through an electrical Depth Telemeter (McNeely 1959) and conventional wire angle-scope ratio calculations. Changes in net depth were normally made by regulating the length of towing cable at the winch.

Preliminary sea trials (1961)

During July and August 1961 a Cobb Pelagic Trawl, made of 4½ inch webbing utilizing plywood hydrofoils in conjunction with Larsson "Phantom" trawl otter boards, was fished 25 times in offshore waters to determine operational characteristics. Most of the 25 tows were set "blind" (no indication of fish). Ten of the tows were made in the deep scattering layers (150 to 200 fathoms) 110 miles off the Washington coast to test the ability of the gear to descend to these depths. These tows produced small amounts of jellyfish, squid, lantern fish, and fanged viper fish. Other blind tows made in shallower depths (less than 50 fathoms) off the mouth of the Columbia River produced occasional silver salmon and up to 160 lb each of hake and jack mackerel. Other species taken in small numbers include blue shark, herring, anchovy. English sole, turbot, and black rockfish.

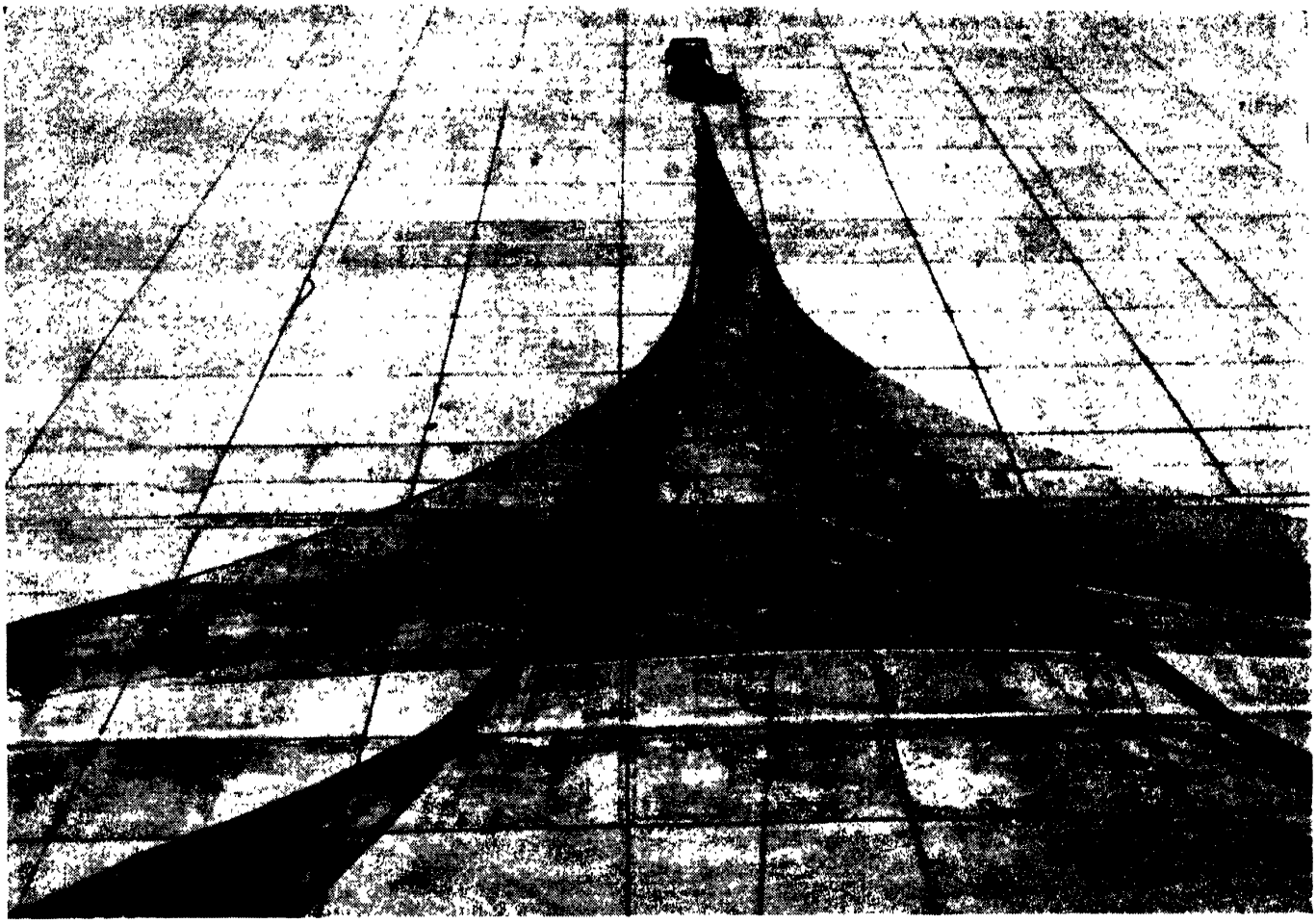


Fig. 11. The man stands inside the after-body of the net which is stretched out three-dimensionally.

Testing of the gear as a salmon sampling surface trawl yielded generally poor results. These drags, made on the Swiftsure Bank, and in Prince William Sound, Alaska, produced salmon in small numbers ranging from a single individual to 29 per drag. Large catches of dogfish shark taken on the Swiftsure Bank repeatedly damaged the net. Catches of dogfish to 10,000 lb were made. During one drag the entire codend was lost and the intermediate section was severely chaffed. Jack mackerel and hake were also taken in amounts up to 200 lb in the Swiftsure area. Although salmon did not appear to gill easily, dogfish, hake and jack mackerel catches usually resulted in severe gilling. A reduction in mesh size from 4½ in (stretch measure) to 3 in was therefore indicated for fish in this size group.

Fishing trials in 1962

In August 1962 the Cobb Pelagic Trawl—Mark II was used during an extensive survey to determine the relative abundance of all pelagic species of fish at pre-determined stations off the coasts of California and Mexico. Following this work, tests of the gear were conducted in nearby waters off Mexico, California, Oregon and Washington to determine its relative efficiency as a biological sampling tool and possible utility as commercial fishing equipment.

(a) Results of offshore pelagic survey

Forty-four predetermined stations were occupied during this phase of testing. Oblique tows from 220 fathoms to the surface were made at each station during daylight hours. At least one of each series of night tows was made on the surface. With the exception of one night surface tow in which 24 mackerel were taken, catch rates seldom exceeded five lb per two hour tow. However, echo-soundings taken at all stations along the track line, which extended over 600 miles offshore, indicated no fish concentrations were available. Scatter recordings were typical of those associated with the deep scattering layers. During part of the offshore survey simultaneous sampling was conducted by the Bureau's research vessel *Black Douglass* using plankton nets and stramin nets. A subsequent correlation (by co-operating scientists at the Bureau's La Jolla Biological Laboratory) of catch rates made during these trials and catch rates made at other times by small, high-speed midwater trawls shows that small, fine mesh nets are as efficient as the Cobb Pelagic Trawl in taking zooplankton and small fishes such as stomatoids and myctophids. Catch rates and sizes of the larger fishes such as anchovy, hake, rockfish, bonito, sardine, mackerel, barracuda, and ribbon fishes (up to 6 ft in length) indicate that the large net was

Underwater Telemeters for Midwater Trawls and Purse Seines

by
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Abstract
Since 1957 the authors have worked on the development of a wireless net depth telemeter for commercial midwater trawling. The general principle and some technical details are given of the five types of instruments built and tried so far in the course of this work. The net depth is measured by determining the hydro static pressure and the measured data are coded into ultrasound signals transmitted to a sound receiver towed by the trawler. They are converted into electrical signals and led by a 25 m long cable to the depth indicator unit in the wheelhouse. The depth indication was first only by pointer on a scale, as well as acoustical. Later a paper-recording system was developed to write the net depth in correct scale on the echogram of the trawler's echo sounder. For the first four instrument types the depth measurements were converted into signals consisting of ultrasound impulses (impulse rate 40 per sec) the duration of which was in linear relation to the depth. Instruments of this kind could not be made light, cheap and rugged enough and continuous depth indication could not be achieved. Then a system of frequency modulation was adopted, i.e., the frequency of a continuous ultrasound signal was changed according to the measured depth. The frequency of the transmitted impulses or signals for all types is approximately 200 kc. The depth-measuring range is 0 to about 250 m with an accuracy of about ±1·0 m at about 100 m depth. The transmission range from net to trawler is about 1,000 m for the first four models and about 2,000 m for the last model. The last model, which is completely transistorised, was found to be satisfactory and is available on the market. Already in 1961 about 70 units were in commercial use, mainly in conjunction with midwater trawling for shrimp in the East China and Yellow Seas. Such depth telemeters are also suitable for measuring the behaviour (sinking speed) and fishing depth of purse seines.

Telemetres sous-marins pour chaluts pelagiques et sennes coulissantes

Résumé
La présente étude décrit le principe général et quelques détails techniques des cinq types d'instruments utilisés par les auteurs qui, depuis 1957, ont travaillé au développement d'un sondeur de filet, actionné par radio, pour chaluts pélagiques. La profondeur du filet est mesurée par la détermination de la pression hydrostatique et les données sont transmises en signaux ultra-sonores codés et reçus à bord du bateau par un récepteur courant. Ces signaux sonores sont convertis en signaux électriques et transmis à l'indicateur installé dans la timonerie. Au début, la profondeur était indiquée sur un cadran ou par signaux audibles; plus tard, grâce à un système enregistreur plus perfectionné, les profondeurs obtenues s'inscrivaient sur l'échogramme de l'instrument de bord. Les quatre premiers types d'instruments convertissaient les données sonores en signaux électriques ultra-sonores (fréquence de 40/sec) dont la durée était en relation linéaire avec la profondeur. Avec cette méthode il était impossible de construire des instruments légers et assez robustes pour un emploi continu. C'est alors que le système de modulation de fréquence fut adopté, c'est-a-dire que la fréquence de l'onde porteuse fut modulée selon la profondeur mesurée. La fréquence de l'onde porteuse, pour tous les types, est d'environ 200 kc et l'on peut mesurer des profondeurs de 0 à 250 mètres avec une précision de ± 1 pour cent à environ 100 m. La portée de la transmission du filet au bateau est d'à peu près 1,000 m pour les quatre premiers modèles et de 2,000 m pour le dernier modèle. Ce dernier modèle, à transistors, est très efficace et est maintenant disponsible sur le marché. Déjà en 1961, 70 unités étaient utilisées par des bateaux de commerce, notamment pour le chalutage des crevettes. Ces instruments sont aussi très utiles pour mesurer la vitesse de descente du filet et la profondeur de pêche des sennes coulissantes.

Continued from page 247

capable of sampling a wide spectrum of the large pelagic vertebrates. In most cases the larger fishes are rarely if ever taken in small, high-speed midwater nets.

(b) Gear efficiency tests

Following the offshore pelagic survey, 16 surface towsand 11 mid-depth tows were made off the coasts of Mexico, California, Oregon and Washington. Catch rates during the near shore tests greatly exceeded catch rates offshore. Although a wide variety of species were taken, the largest catches consisted of 1,850 lb of hake, 1,900 lb of mixed sablefish and hake, 1,000 lb of anchovy, and 600 lb of ocean sunfish. Most of the larger catches were made at mid-depth.

Conclusion

Utility of the Cobb Pelagic Trawl for gross biological sampling[2] was demonstrated during sea trials of the gear by the wide variety of fishes taken—seventy, in fact. Those sets made on schools of fish located by echo-sounding in depths greater than 30 fathoms usually produced fair amounts of fish. Attempts to capture surface swimming schools usually resulted in poor catches.

It should be noted that the total number of drags made to date is small and has entailed many variables inherent in development of new gear.

Notes

1. In other gear experiments conducted during 1961 and 1962 involving use of a giant, small-mesh fyke net to strain the total discharge of water from hydro-electric turbines, the author has found incremental hang-in to be a distinct advantage to counter distortion of meshes near the mouth of the net.

2. Towing at predetermined stations without prior echo-sounding or other observations to determine the presence of fish.

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Telemetros submarinos para redes de arrastre flotantes y de cerco de jareta

Extracto

Trabajan los autores desde 1957 en la fabricación de un telémetro inalámbrico registrador de la profundidad a que está la red, para los artes flotantes empleados en la pesca industrial. Se dan los principios generales y algunos detalles técnicos de los cinco modelos de aparatos construídos y ensayados hasta ahora. La profundidad a que se encuentra el arte se mide determinando la presión hidrostática y los datos se transforman en señales ultrasonoras y se transmiten a un receptor que remolca el arrastrero en el que se convierten en señales eléctricas y a través de un cable de 25 metros pasan al grupo indicador de la profundidad situado en el puente de mando. En un principio la profundidad se indicaba solamente mediante un puntero en una escala y acústicamente; mas tarde se ideó un sistema de papel registrador en el que aparecía la profundidad del arte en la escala del ecograma de la ecosonda del barco. En el caso de los cuatro primeros modelos la medida de la profundidad se convertía en señales que consistían en impulsos ultrasonoros (40 por segundo) cuya duración estaba en relación aritmética con aquélla. Los aparatos de esta clase no lograban hacerse lo bastante ligeros, robustos y baratos y por ello no se obtenía una indicación continua de la profundidad. Posteriormente se adoptó el sistema de modulación de la frecuencia, es decir: la frecuencia de una señal ultrasonora continua se transformaba de acuerdo con la profundidad medida. La frecuencia de los impulsos o señales transmitidos por todos los aparatos es de cerca de 200 kc. La escala para medir la profundidad va de 0 a cerca de 250 m, con una exactitud próxima al ±1 por ciento a cerca 100 m. El alcance de la señal transmitida desde la red es de unos 100 m en los primeros cuatro modelos y de unos 2,000 m en el ultimo. Este está completamente transistorizado, da resultados muy satisfactorios y se encuentra ya en el comercio. En 1961 se empleaban industrialmente unos 70 aparatos, principalmente en la pesca del camarón con artes pelágicas en el mar del este de la China y en el Amarillo. Estos telemétros también se pueden emplear para medir la velocidad a que se hunden y la profundidad a que pescan los artes de cerco de jareta.

SUCCESSFUL midwater trawling requires knowing the net depth under various conditions. Since 1957, the author and his colleagues have been doing research on midwater fishing gear and methods and on underwater telemetry for midwater trawling. Five kinds of telemeters were designed and manufactured in four years. The latest design, Type V, has been installed in fishing boats and is performing satisfactorily. About 70 sets are in use in one-boat and two-boat midwater trawling in the Yellow Sea and other fishing grounds. This telemeter has also been adapted to purse seining.

As is known, the depth of the net, even if warp length and towing speed are constant, can vary due to the influences of currents and wind.

In order to keep the trawl at a desired depth, it is therefore necessary to have continuous net depth measurements by means of a suitable depth meter. The actual problem for such depth telemeters is not so much the measurement itself but the transmission of the measured data from the net to the boat. With the telemeters described here, this is done by wireless ultrasound signals.

The first instrument (Type I) was completed in November 1958. This was gradually improved into Type II. In January 1960, Type III and in February 1961 Type IV were developed. Type V, which contains further innovations, was completed in June 1961. It is now used in commercial operation in East China and Yellow Seas.

The complete net depth telemeter consists of the depth meter and signal transmitter, the signal receiver and the

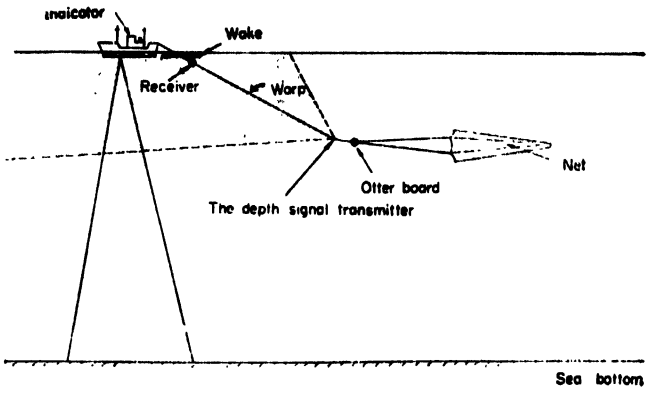

Fig. 1. Arrangement of wireless depth telemeters with midwater trawls.

depth indicator. As shown in Fig. 1, the depth meter and signal transmitter unit, which transmits signals corresponding to the depth of the meter, is attached to one warp close in front of the otter board (or the wing tip). In order to evade the interference of the propeller wake of the trawler, the receiver is also attached to the warp in sufficient depth about 25 m astern of the trawler. The ultrasound signals are converted by the receiver into electrical signals which are transmitted by cable to the depth indicator on board the trawler.

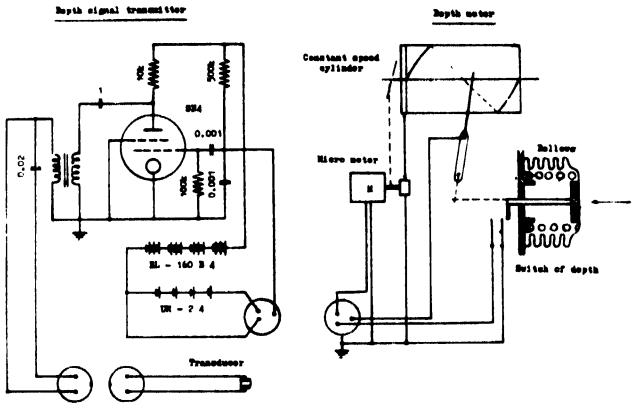

Fig. 2. General construction of depth meter and signal transmitter

Fig. 2 shows schematically the structure of the depth meter and signal transmitter (Types I to IV). For the net depth the hydrostatic pressure is measured by a set of bellows. The displacement of the diaphragm in proportion to the depth actuates a pointer which has contact with a wire spiral on a cylinder which is driven at constant speed by a micromotor. Since the pointer moves in the direction of the axis of the rotating cylinder in accordance with the depth, the period during which it is in contact with the spiral is proportional to the depth. For this period the signal-transmitting circuit is closed and ultrasound impulses of 200 kc are transmitted at a frequency of 40 per sec. This impulse frequency is effected by a commutator attached to the axis of the micromotor. The duration of the signal of 40 impulses per sec. thus indicates the depth measured by the bellows.

Variations of the voltage of the electrical source are irrelevant to the accuracy of the measurements.

There is one main shortcoming of this system, i.e., measurements are not continuous but can be transmitted only at the rate of one per rotation of the cylinder. In the Type I to IV meters the cylinder was designed to rotate once every 10 sec so that measurements could be transmitted once every 10 sec which was considered sufficient for practical fishing.

A pressure switch was provided to cut off the transmitter in less than 8 m water depth to avoid waste of the battery. The ultrasonic transmitter and receiver were of the same type, i.e., barium titanate, 30 mm diameter, beam angle approximately 20°. The unit is shown in Fig. 3, A. The ultrasound receiver (Fig. 3, B) converts the received sound signals into electrical signals which, by means of a 25 m long cable, are conducted to the indicator unit in the wheelhouse of the trawler.

The indicator unit (Fig. 3, C) consists of the amplifier,

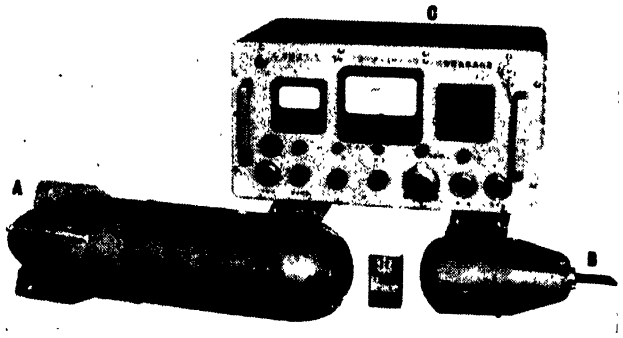

Fig. 3. The wireless net depth telemeter Type I. A—depth meter and signal transmitter. B—receiver. C— indicator.

the depth-evaluating part, the depth indicator (with loudspeaker) and an electrical power source. The depth indicator is located near the centre of the instrument panel, and on both sides of this are a voltmeter for the electrical source and the loudspeaker. The depth signal is amplified and led to the depth evaluation part where it is converted into a voltage proportional to its duration. Thus the depth is indicated directly by a voltmeter with depth calibration. A filtering circuit at the input side of the depth indicator eliminates the disturbances caused by external noise. An additional output circuit is provided to make the depth signals also audible through a loudspeaker. When the distance to the net becomes too great (and the signal-input too weak) the depth indicator may not indicate even at maximum amplification. In such cases the depth can be estimated from the duration of the audible signals. The audible signals also help to determine whether faults of the instrument lie in the depth meter and signal transmitter or in the receiving parts. Finally the audible display helps to find the best position for the receiver.

The Type I depth meter was designed for: range of depth measurement 0 to 250 m, range of transmission over 1,000 m, accuracy of depth measurement within ±1 per cent, maximum depth for the depth meter and transmitting unit 500 m.

Since the directional beam angle of the transmitter and the receiver is rather narrow, it is best to attach the depth meter and transmitter unit at the end of the warp; that is, right in front of the otter board in the case of one-boat trawling or right in front of the wing tip for two-boat trawling. The receiver is also attached to the same warp but short astern of the trawler and just below the propelling wake. The attachment of transmitter and receiver to the warp has to be made so that they face each other over the distance as directly as possible.

From December 1958 to September 1959 various theoretical and practical experiments were conducted with satisfactory results on Type I.

The Type II meter developed on the basis of these experiences incorporated the following improvements:—

(1) The outside diameter of the depth meter and transmitting unit was decreased by 20 mm to 120 mm.
(2) To cover the interval of 10 sec between two

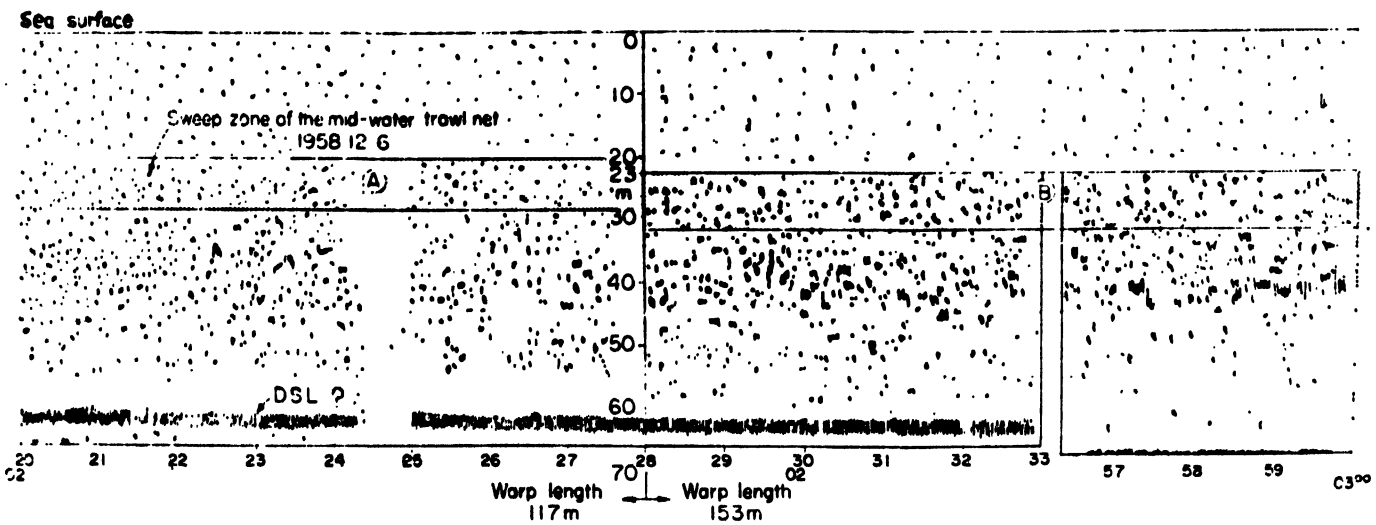

Fig. 4. Schematic drawing of a fishfinder echogram with superimposed measurements of the net depth at different warp lengths.

depth readings, the indicator was made to maintain a constant reading till the next signal.

(3) The frequency filter (40 cycles) was made variable, so that it could follow the variations in the revolutions of the micromotor of the depth-signal transmitting unit. This was done by lowering the voltage of the electrical source. (In the Type I meter such variations showed up as an error.)

(4) The noise-eliminating circuit was improved, and the false movement of the indicator was decreased.

(5) The correction of the depth indicator during operation was made possible. Furthermore, in Type I the time-measurement was done with a stopwatch, whereas in the new type it is done electrically.

(6) The indicator was made into a separate unit, so that it could be placed on the recorder of the fish-school detector, and the rectifying circuit was improved to eliminate the chattering of the relay, which was liable to occur in Type I.

(7) The sound receiver was streamlined, so that the eddies which it forms would be minimised. Furthermore, the beam angle was changed to 8° vertically and 20° horizontally, to simplify the directional adjustments.

In the Type III meter the depth indication was developed for recording, superimposed on the echogram of the trawler's fish-finding echo sounder. The recording of the depth meter is delayed on the echogram according to warp length, trawling speed and paper transport.

With this arrangement the adjustment of the net to the fish schools detected by echo sounding is simplified considerably. By recording also the variations of the tension on the warps on the same paper the performance of the trawl can be judged to a certain extent and the amount of catch obtained can be estimated (Fig. 5).

The Type III meter has already shown satisfactory results in catching croaker and Taisho prawns. The depth meter and transmitting unit is in general the same as that of Types I and II, but further reduced in diameter to 102 mm. Since the tension is also recorded, a depth-tension signal converter was newly installed.

The Type IV meter which was finished in February 1961 is a further improvement. It is still smaller and more practical than the former types. It is more rugged and resistant against mechanical impacts and achieved a lightweight miniaturisation of the transmitter. However, the modulation method of the depth signal and the measuring principle remained exactly the same. Therefore, the transmission of the depth-signal is still made at intervals of about 10 sec, and the complexity and the problems involved with the handling of the instrument were much the same as with the former Types.

Type V (Fig. 6) was first produced and tested by the

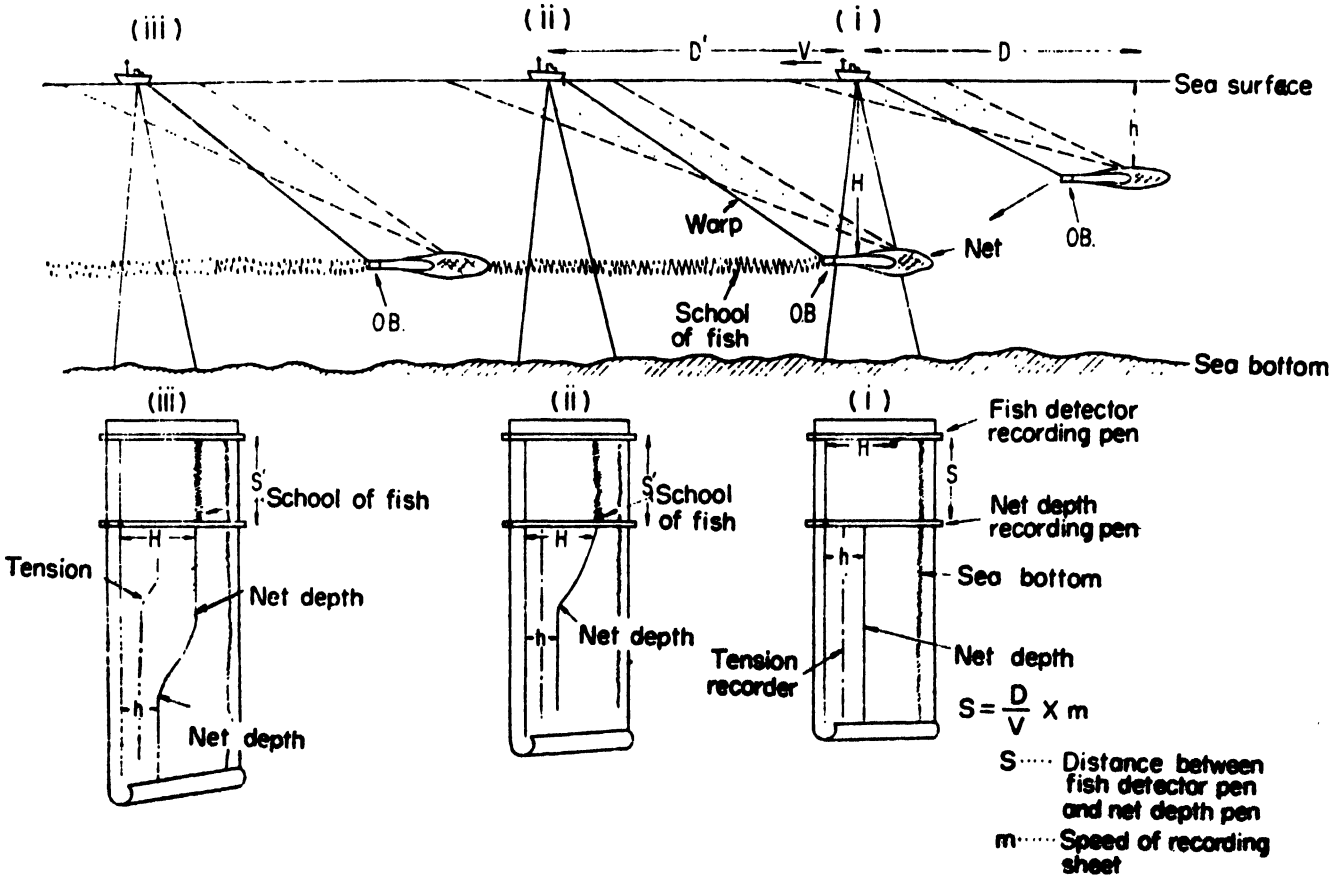

Fig. 5. Schematic sketch of midwater trawling with recording echo sounder, wireless net depth telemeter (Type III) and tension meter for the warps.

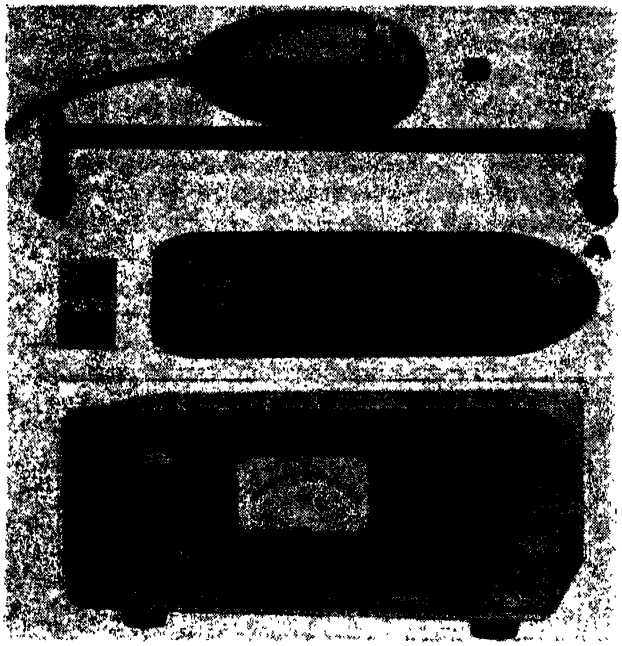

Fig. 6. The wireless net depth telemeter Type V. A—depth meter and signal transmitter. B— receiver. C—indicator.

authors in July 1960. It was meant to eliminate the various shortcomings of the earlier makes, such as:—

(a) Ten-second intervals between depth readings.
(b) Complicated construction.
(c) Too many mechanical parts, making the instruments too delicate to be protected efficiently.
(d) High weight of the depth meter transmitter unit, making it difficult to handle and operate.
(e) High price.

To overcome these shortcomings a completely different method of coding and transmission was adopted, i.e., conversion of the variations in depth into frequency variations. As with the former instruments the net depth is indicated on the dial directly, and it can also be recorded on the echogram of the fish-finding echo sounder of the trawler. In this way the depth of the net is indicated continuously and without interruption. The instrument is entirely transistorized to reduce electric power consumption (electric power consumption of transmitter: 300 mW; electric power consumption of indicator 1·2 W) and to make small and lightweight construction possible. The transmitting range is increased to more than 2,000 m. Handling and operation is simplified considerably, and the price is reduced to almost half of that for Types III and IV. This instrument (Fig. 6) was first completed and tested in June 1961 with a midwater trawl and both the sensitivity and accuracy were found quite satisfactory.

The specifications of Type V are:—

(1) Depth measuring ranges: 10 to 130 m. Accuracy ±0·5 m.; 20 to 240 m. Accuracy ±1·0 m.
(2) Range of transmission from transmitter to receiver: about 2,000 m.
(3) Beam angle of acoustic signals: 40°.
(4) Maximum depth for depth meter and transmitter unit: 500 m.
(5) Depth meter indication: For direct reading and recording of the net depth from the water surface.
(6) Power source: For indicator: A.C. 100 V, 60 cycles;
For transmitter: 6 dry cells of 1·5 V each in series giving continuous operation for 40 hours.

A combined recording of this telemeter on the echogram of the trawler's echo sounder is shown in Fig. 7.

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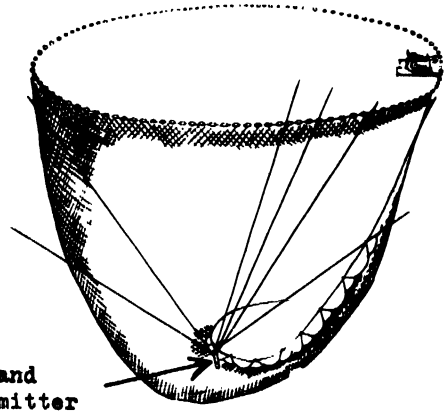


Fig. 8. Mode of application of a depth telemeter to the leadline of a purse seine.

Fig. 7. Echogram of the trawler's fish finding echo sounder with superimposed net depth recording of the telemeter Type V.

Reaction of Herring to Fishing Gear Revealed by Echo Sounding

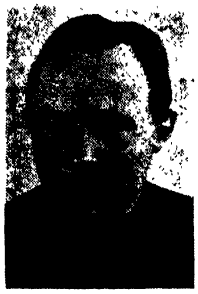
Abstract
For successful midwater trawling, the behaviour of the fish towards the gear is of particularly great importance, because fish have a better chance to evade midwater trawls than, for instance, bottom trawl gear. Fish behaviour studies are therefore of great value for the improvement of midwater trawling. All the different means of observing fish behaviour, such as diving, television, filming of actual conditions, or aquarium experiments, have their advantages and disadvantages. For the present studies which were made, along with German midwater trawling trials in recent years, the echo soundings taken by the trawler's echo sounder and the "netzsonde" were utilised. The "netzsonde" is a recording echo sounder on board the trawler, connected by cable to a transducer mounted on the headline bosom of the trawlnet. By sounding vertically downwards, the "netzsonde" records the distance of the net from the sea bottom, the opening height of the net mouth and fish in and below the net opening. It was found that herring (*Clupea harengus*) is easier to catch when spawning because it then occurs in dense schools and it does not react strongly to the gear. Otherwise, the herring is much more active and may evade midwater trawls, particularly when dispersed. Relatively small one-boat midwater trawls have therefore been reasonably successful in catching spawning herring on some occasions, although much inferior to the larger two-boat midwater trawls for catching non-spawning herring. Since such active herring usually keeps at several metres distance from lines and netting in the netmouth, the difference in the size of the "effective net opening" is even more pronounced, and this is to the disadvantage of smaller nets. Sprat (*Clupea sprattus*), which otherwise showed similar schooling and migration patterns, proved to be much easier to catch than herring. Mackerel (*Scomber scombrus*) reacts to midwater trawls in a way similar to non-spawning herring. Dogfish (*Acanthias vulgaris*) does not seem to react to midwater trawls at all.

Etudes au moyen d'echo-sondeur, des reactions des harengs aux engins de pêche

Résumé
Les chances d'évasion du poisson étant plus grandes dans le chalutage pélagique que dans le chalutage de fond, l'étude du comportement du poisson envers les engins de pêche est très importante. Tous les moyens d'observation utilisés comme: plongées, télévision sous-marine ou expériences en aquarium ont leurs avantages et leurs inconvénients. Ces études ont été menées au cours d'essais effectués par des chaluts pélagiques utilisant les enregistrements des échos-sondeurs de bord et du "Netzsonde". Le "Netzsonde" est un écho-sondeur dont le système enregistreur est installé à bord du chalutier et relié par câble à l'émetteur qui est fixé sur la corde de dos du chalut. En sondant verticalement le "Netzsonde" enregistre la distance entre le filet et le fond, l'ouverture du filet et le passage du poisson dans le filet. Le expériences ont prouvé que le hareng (*Clupea harengus*) est plus facile à prendre pendant le frai parce qu'on le recontre alors dans des bancs épais qui ne réagissent pas vivement à l'approche de l'engin de pêche. En dehors de cette période, le poisson est beaucoup plus actif et peut s'évader du chalut pélagique. C'est ainsi que les petits chaluts pélagiques ont eu certains succès sur le hareng en période de frai et que les chaluts pélagiques tirés par deux bateaux en ont eu beaucoup plus sur les harengs qui ne fraient pas. En dehors de la période de frai les harengs se tiennent à une distance de quelques mètres des lignes du filet, dans l'ouverture et le résultat est de ce fait, beaucoup plus désavantageux pour les petits filets que pour les grands. Les espeots (*Clupea sprattus*) dans les bancs se comportent comme les harengs et sont plus faciles à capturer; les maquereaux (*Scomber scombrus*) réagissent de la même façon que les harengs actifs, c'est-à-dire en dehors de la période de frai. Les chiens de mer (*Acanthias vulgaris*) n'ont aucune réaction à l'approche du chalut pélagique.

Reaccion del arenque ante los artes de pesca estudios por medio de la ecosonda

Extracto
Para que la pesca al arrastre entre dos aguas dé buenos resultados, reviste especial importancia conocer el comportamiento de los peces ante los artes por ser más probable que eludan los pelágicos que los de fondo. El estudio de tal comportamiento es necesario para mejorar el arrastre pelágico. Todos los procedimientos de observarlo, entre ellos el buceo, la televisión, las películas de las condiciones reales o los experimentos en los acuarios tienen ventajas e inconvenientes. En los estudios de que trata el autor, realizados simultáneamente con ensayos de artes de arrastre pelágicos alemanes, se emplearon las indicaciones dadas por la ecosonda y la "netzsonde" del arrastrero. La "netzsonde" es una ecosonda registradora instalada en el arrastrero y conectada mediante un cable a un transductor montado en la visera del arte. Sondeando verticalmente hacia abajo la "netzsonde" registra la distancia desde la red hasta el fondo, la abertura en altura del arte y los peces ante la boca y debajo. Se ha observado que el arenque (*Clupea harengus*) se pesca más fácilmente cuando desova porque se reúne en espesos cardúmenes y no reacciona vigorosamente ante la red. En otros momentos despliega mucha más actividad y puede eludir los artes, articularmente si está muy desperdigado. Debido a ello, los artes de arrastre pelágicos remolcados por una embarcación pequeña han obtenido resultados satisfactorios, en algunas ocasiones, en la pesca del arenque en desove, aunque estos resultados han sido muy inferiores a los logrados con artes pelágicos remolcados por dos embarcaciones dedicadas a la pesca del arenque que no desova. Como los arenques activos se mantienen a varios metros de distancia de los cables y de la boca del arte, la diferencia en las dimensiones de la abertura eficaz del arte es todavía mayor y va en perjuicio de los artes más pequeños. La sardinita (*Clupea sprattus*), que mostraba las mismas modalidades de formación de cardúmenes y movimientos migratorios, resultó ser mucho más fácil de pescar que el arenque. La caballa (*Scomber scombrus*) reacciona ante los artes pelágicos de manera análoga al arenque que no desova, en tanto que la mielga (*Acanthias vulgaris*) no parece reaccionar en absoluto.



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IN recent years many investigations on midwater trawling for herring have been carried out by the Institut für Netzforschung, Hamburg. The vessels

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Such telemeters can also be used to ascertain the actual depth of purse seines. A possibility of application at the leadline is shown in Fig. 8. As it would be difficult to direct the sound beam accurately enough, it is desirable to have a wide beam with circular cross-section and the transmitter should, therefore, be circular.

Acknowledgments
All these instruments were produced by the Furuno Electric Co., Ltd., and we are indebted to Mr. Junichi Fukiwara of this company for his kind co-operation.

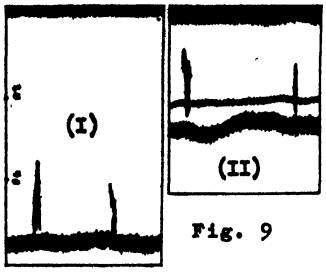

Fig. 9

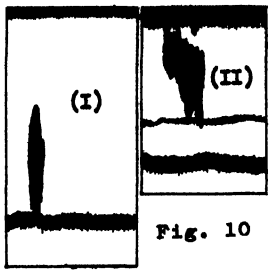

Fig. 10

Fig. 9. Dense schools of spawning herring, "towers" on Aberdeen Bank (I) are now frightened by midwater trawl gear. The footrope cuts clear through the schools (II). The two small traces on the "netzsonde" echogram represent a catch of four tons.

Fig. 10. A "tower" of spawning herring near the English east coast (I). The strong trace on the "netzsonde" echogram represents a 20-ton catch.

20 tons. The total towing time of this haul was 8 min. The whole catch was collected in only 2 min. The two small traces in Fig. 9b represent a catch of four tons. These catches consisted entirely of fully mature herring with eggs and sperm flowing (August 1962). Both hauls were made with the small type one-boat midwater gear which had given very poor results with non-spawning herring. It may well be that these pelagic schools constituted a preliminary phase of spawning, whereas the proper spawning takes place close to the bottom.

Fig. 11 shows a "netzsonde" echogram of herring,

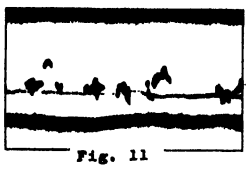

Fig. 11

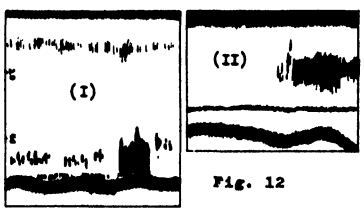

Fig. 12

Fig. 11. Spawning and partly spent herring in the English Channel showed no reaction to midwater trawl gear.

Fig. 12. "Plume" and "steeple" traces of spent herring on the feeding grounds (Swallow Hole) (I). While the small schools escape, part of the larger school is caught by a one-boat midwater trawl (II).

both spawning and already partly spent, from the English Channel (December 1961). The small but dense groups are not scared by the approach of the footrope though it is quite possible that these small packs are not the normal type of spawning schools as numerous boats were fishing in a very small area.

(c) With herring at the feeding grounds the catches were very heterogeneous, and consisted of all maturity stages ranging from virgin herring to spents forming different schools in different layers.

During day-time in the area around Swallow Hole (western North Sea) in October 1962 mainly two types of herring schools could be distinguished: (i) small separate groups, "plumes"[5], forming a layer in a depth of 50 to 60 m in midwater; (ii) "towers" and "steeples" sometimes beginning 40m below the surface and reaching down to the bottom (70 to 80 m) and (iii) greyish layers close to the bottom (70 to 80 m) resembling the schools at the Norwegian Deep but smaller in extent.

Catches of (i) and (ii) consisted of a high percentage of spent herring and recovering spents. Hauls of two-boat trawlers were generally successful (Fig. 12). The fish usually kept to a distance of 2 to 4 m from the net mouth. One-boat trawlers with smaller gear failed to make good catches in the layers of small schools which normally disappeared entirely before the net reached them; also when fishing for big "steeples" only a few hauls were satisfactory.

The greyish layers close to the bottom[3] consist mostly of pre-spawners which reacted like the non-spawners at the Norwegian Trench (Fig. 13).

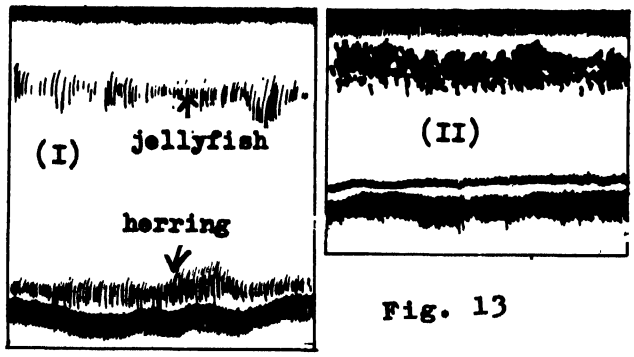

Fig. 13

Fig. 13. Pre-spawning herring near the bottom of Swallow Hole (I) show similar reactions to midwater trawls (II) as the hibernating pre-spawners at the Norwegian Trench.

Echoes of other fish species

Other pelagic species were caught accidentally or by design. In Autumn 1962 in the western North Sea and Irish Sea traces of sprat on the ship's echo sounder were indistinguishable from those of spent herring. (Figs. 14 and 16.) On the "netzsonde" echogram,

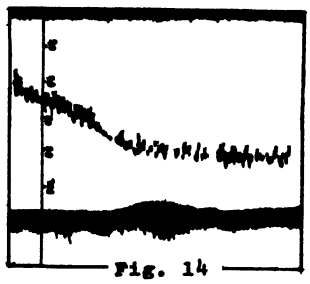

Fig. 14

Fig. 15

Fig. 14. Sprat (Clupea Sprattus) *schools in the Irish Sea give similar traces to spent herring. They also descend with increasing daylight.*

Fig. 15. During ascent at dusk, the small sprat schools in the Irish Sea scatter widely before forming a layer near the surface.

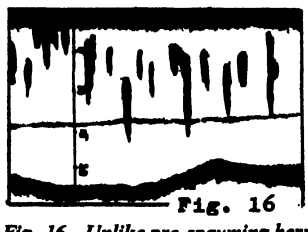

Fig. 16

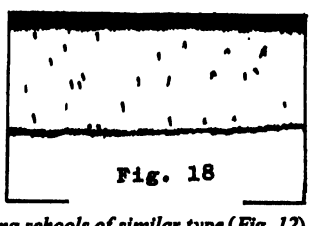

Fig. 18

Fig. 16. Unlike pre-spawning herring schools of similar type (Fig. 12), sprat in the Irish Sea could easily be caught with a small one-boat midwater trawl.

Fig. 18. Widely spread single dogfish (Acanthias vulgaris) *at the Norwegian Trench showed no reaction to midwater trawl gear.*

however, where the traces appeared in the same shape because they were not frightened by the net mouth, they were quite recognisable as those of sprat (Fig. 16).

Sprat was found to make daily vertical movements similar to the herring. The descents were very regular but during ascent the schools scattered widely.

Mackerel were sometimes mixed with herring. Off the Norwegian coast they occasionally formed separate schools of a shape similar to that of the "towers" of herring non-spawners (Fig. 17). The schools were obviously compact and thoroughly scared by the headline and footrope[4] whereas dogfish showed no reaction to the net mouth even when in very loose schools (Fig. 18).

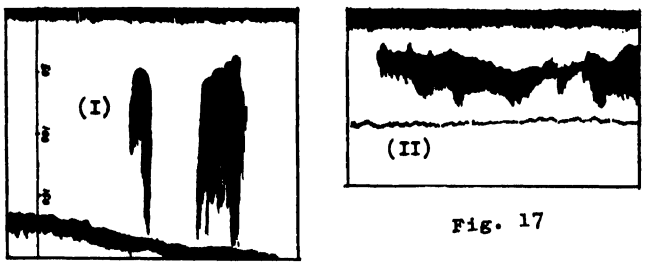

Fig. 17

Fig. 17. Mackerel (Scomber scombrus) *schools at the Norwegian Trench had similar shape (I) and showed similar reaction to midwater trawl gear (II) as non-spawning herring.*

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Discussion on Midwater Trawling

Dr. J. Schärfe (Germany) Rapporteur: Attempts to develop a one boat midwater trawl started about 10 years ago after the pair trawling technique had proved that fish can be caught with trawls in mid-water. Due to the hydrodynamic problems involved in the design and rig of otter boards for efficient and stable operations off the bottom, the development of one boat midwater trawling was mainly undertaken by or under the guidance of private engineers or governmental institutes and almost simultaneously in several countries. The problem was therefore tackled in a more technical and even scientific way, employing rational means like precalculation, model and full scale tests and a sizeable variety of measuring and observing techniques and instruments. As a result a number of one-boat midwater trawls have been developed. All these gears are suitable for operation from conventional side or stern trawlers of the respective country, employing as little additional equipment or skill as possible. The trawl winches and warps are taken over unchanged from bottom trawling.

For the otter boards a number of different versions are used. Okonski describes a slightly modified conventional rectangular flat otterboard. Such boards have also been used in various rigs by other workers. They have the advantage that they are most easily accepted by fishermen but hydrodynamically they are inferior to the more generally employed hydrofoils which are certainly indicated for conditions where towing power is to be utilised to the best advantage. The full profiles of Larsson and of other designs described by McNeely are perhaps slightly more efficient but on the other hand also more costly and less rugged than the well known Suberkrub design. Most designs employ one pair of otter boards rigged with G-hook and Kelly's eye as habitual in bottom trawling. The boards may be adjusted for some downward sheer, as described by Okonski, or with a speed dependent component for upwards sheer (Sueberkrub design). They may also be rigged partly for an upward and partly for a downward sheer as described by McNeely for gear with two pairs of otter boards. Stable action of the boards is sought either by designed combination of adjustment and ballast at the lower edge only, or by additional flotation.

The legs connecting the net with the otter boards are mostly steel wire cables or combination manila wire rope with lengths between 60 and 150 m. They are normally hauled on the trawl winch. To avoid twisting together, the legs of each side of the gear should be of opposite twist. The headline and footrope legs can be of equal or of different lengths depending on the position of the otter boards desired in regard to the net. If the headline legs are longer, as described by Okonski, the otter boards will touch bottom earlier than the net and the warps will sweep more of the water in front of the net than when the headline legs are shorter than the footrope legs. This adjustment can be significant for trawling off or on the bottom at will.

In the nets themselves the four-side seam type consisting of four equal panels has been taken over for most designs from pair trawling. An exception was the trawl net described in his own (Dr. Schärfe's) paper. There, the two-seam type, or a completely different four-seam type with one pair of equal and one of unequal panels were used. The two-seam type is somewhat like a modified Vinge trawl. Although this type was found to perform technically to full satisfaction the catching efficiency for non-spawning herring in the North Sea did not meet expectations. This was probably due to insufficient opening size of the net mouth and unfavourable mesh shape. Since two-seam trawlnets can be tapered only along four edges, they are rather long in relation to the circumference of the opening and the size to which this type can practically be built is therefore limited. The four-seam type with eight edges to taper, has so far been made up to 1,400 meshes circumference and about 100 m in length and proved more satisfactory in trials.

Unless four otter boards are employed, the net opening in vertical direction must be secured by special shearing devices or by weights and floats.

Most mid-water trawls are handled in practically the same way as bottom-trawls, that is on sidetrawlers the usual auxiliary ropes as quarter ropes and poke lines are employed and large catches are taken on board by splitting.

Midwater trawling operations, however, require some additional skill and means for efficiently coping with the third dimension. Accurate fish detection by echo sounding is, of course, a *conditio sine qua non*, and echo ranging is highly desirable. The net must be brought into and towed in the depth of the fish schools, which means it must not only be easily manoeuvrable but its position or movements must be observable, preferably continuously. Most commercial midwater pair trawling for herring in northern European waters is still done without any depth meters but the limitations of this practice need not be stressed. It may suffice for relatively small vessels fishing under favourable conditions but for costly vessels and varying fishing conditions more accurate net depth telemeters are essential.

The echo sounding Netzsonde technique gives not only the net depth but also the opening height of the net mouth and showed the fish in and under the net opening and is therefore considered particularly suitable, in spite of the problems connected with the separate cable. The depth of the midwater trawl is regulated by warp length and towing speed. Quick manoeuvrability requires, therefore, a powerful trawlwinch, preferably with centralised control for veering and hauling, and an as efficient and simple propulsion control as possible, preferably directly from the wheelhouse, as can be obtained for instance with variable-pitch propeller or diesel-electrical drive. The lack of these facilities of course does not prevent midwater trawling, but it makes operation a bit slow and less convenient. For one-boat midwater trawling, stern trawling technique appears to be superior to side trawling. Apart from the operational advantages, the distance between the gallows at the stern is added to the opening width of the trawl gear and the warps are kept more apart, which should both favour catching efficiency.

In spite of the reasonably good technical performance already achieved by one-boat midwater trawls, it is still felt that the basis on which development work of this kind has to rely is not yet sound enough. There is need for more International co-operation and reports about active attempts to fill this gap in knowledge by co-ordinated basic research. Such research is needed perhaps more in regard to the interaction between fishing gear and the fish. In spite of technically satisfactory performances the catching results of one-boat midwater trawls under many conditions are rather disappointing, particularly in comparison with pair trawlers. This illustrates clearly that the gear is still being developed. There is no doubt that good progress has been made since the first Fishing Gear Congress. This however is unfortunately not well enough shown by the papers submitted to this Congress. There are, for instance no records on the situation in Norway and France, where commercial one-boat midwater trawling has developed.

Midwater trawling is supposed to fill the gap between the working range of conventional near-surface and bottom fishing gear, for better exploiting known fish stocks and for opening up so far untapped resources. Although many high expectations in general have not been fulfilled yet, the present situation and the future development so far as it can be foreseen from the current efforts, are promising enough, and interesting results can be expected in the near future.

Mr. K. H. Larsson (Sweden): Twenty years ago I got interested in trawl gear from a technical point of view and started my private research work. Having thoroughly studied available papers dealing with midwater trawling, I would like to give my impressions of the improvements in the techniques of pelagic trawling made in these two decades.

It is overwhelming to note how much work has been done around the world especially during recent years. Possibly much money could be saved by some international co-operation. Research work is rather expensive so it is satisfactory that a degree of International team work has started. I would, however, recommend research organisations not to forget those funny people called inventors. They very often have good ideas and like most other people, they want to be paid for their work.

I quite agree with Messrs. Dale and Moller in saying that "the ideas arising from technical research seemed too revolutionary and upsetting to many people". I would add, however, that to base design of midwater trawl gear on technical theories and experience will be the only way of reaching good results.

A common trend seems to be the desire that trawl gears should be used on the bottom, just off the sea bed, and in midwater. Perhaps the English word "hovercraft", a sort of floating craft moving just above the surface of the sea, can be applied so that an all-round trawl gear will have to be a "hover trawl".

In 1944 at Gothenburg I tested a model of an ordinary bottom trawl to study its resistance. Then man-made fibres were hardly known so it was not thought possible to decrease resistance. Thus I concentrated on the design of the trawl boards and found that if the trawl boards were lifted from the bottom of the tank their sheering ability increased by about 32 per cent.

On behalf of the Swedish Navy I continued in 1945 testing hovering trawl boards in order to design mine-sweeping gear for picking up mines, torpedoes, aircraft and so on from the sea bed in harbour entrances. In sheltered sea waters fifteen different types of trawl boards were tested. A hovering trawl board must have perfect stability and good sheering capacity. I soon found that by increasing height in relation to breadth, sheering power was increased. Definitely the best type of trawl board was the wing board which looks like an airplane wing standing upright in the water. This type of hovering board has a sheering power just twice that of the ordinary flat board on the sea bed. Its angle against the towing direction was only 13 to 14 degrees compared with 30 to 35 for the flat trawl board. This gave very low resistance and a perfect and steady movement straight ahead.

In his paper Mr. McNeely describes a hydro-foil otter board with a height to breadth ratio of little more than $1\frac{1}{2}$. From my report to the Swedish Navy I could give Mr. McNeely full information of the sheering ability of his board as I tested a board almost exactly of that design. A model like the Suberkrub trawl board was also on my test list in three different makes with height to breadth ratios of 1·5, 2 and 4.

It is encouraging that hydro-foil trawl boards are coming more and more into use. It would be reasonable to say that all testing of midwater trawls with low flat rectangular trawl boards is a waste of time.

To the merits of the hover trawl I would add the experience that very little spawn and small fish is caught by a trawl which moves just off the sea bed. And a trawl of that type would not harm underwater cables. Other points in designing a good midwater trawl are, trawling speed, size of net meshes,

frightening of fish in front of trawl mouth, and pressure in the water in front of the trawl mouth.

The two-boat trawl has the great advantage of the warps frightening the fish in towards the trawl net whereas the warps in front of a one boat trawl will to a certain extent frighten fish away from the trawl mouth. This can be overcome in different ways. One is for a certain trawl net to increase the size of the trawl boards, whereby the distance athwartships between the boards would increase. Dr. Schärfe in his paper says this has been done with good results. Lengthening of the pulling line between the trawl boards and the trawl net will also help. Another way, is to arrange so that the trawl net moves lower down in the water than the trawl boards do. In my experience such an arrangement is good. Regarding suitable trawling speed, very different ideas are found in the papers. McNeely describes a trawl with a very big net calculated for a speed of only 2½ knots. I would not be quite happy if I had to work with the trawl he describes. It must be very expensive and the handling of the total gear with four trawl boards on two warps would mean much heavy handwork for the men on deck.

European tests show high trawl speed is essential for good catches. Dr. Schärfe, in one report, says that for summer fishing the highest possible speed is necessary and that it should be investigated whether it would be possible with higher speeds and new design of gear, to avoid frightening fish in front of the net mouth.

When balls are used as floats on the headline, the speed is definitely limited. If one passes that limit the resistance of the balls will press the headline backwards and thus decrease the height of the net opening. Dr. von Brandt establishes this and urgently recommends the use of special types of kites instead of balls.

Russian tests have given the same experience and they suggest a profiled kite of improved design for direct and simple attachment to the trawl.

As early as the Autumn of 1945 I had made the same observations. After tank tests in April 1946 and practical tests up till 1949 the so-called trawl toad was born. It is a self-stabilising trawl paravane of advanced design which can be attached to the headline by a single rope. Its lifting capacity increases with the square of the speed. Two different types are made, one pulling up and the other pressing down, so they can be attached to the headline as well as to the footrope. German tests reported by Dr. Steinberg in April 1960 demonstrated that with trawl paravanes on headlines and footrope, the net opening will be the same regardless of trawling speed.

Mainly on account of manufacturing difficulties trawl paravanes of my design have been sold mostly for research purposes. The plastic industry, however, now offers great possibilities for making them on a large scale. Once they are on the market I am sure they will demonstrate their capacity and make it possible to design an effective high-speed hover trawl.

For such a trawl design I propose: (1) the trawl net should have a rather small area of mouth—about half of an ordinary trawl and be made of net with big meshes. This means less resistance and decreased pressure in the water in front of the net mouth. (2) There should be only very few floats and weights on the headlines and footropes as at high speed the pressure in the trawl net would give an almost ideal shape, that is, with circular sections. (3) The trawl net should have two seams and be shaped like a parachute. (4) In order to give good catching ability two or more frightening lines are to be arranged athwartships at certain distances in front of the trawl mouth, each one with a number of self-stabilising paravanes to lift the upper lines and pull down the lower ones. These lines will frighten the fish in towards the centre lines of the net. Trawl boards of perfect shape should be used. This arrangement of a trawl has been patented.

Hamuro and Ishii's description of a new instrument for giving the depth of the midwater trawl is most interesting. As it works without direct cable connection between trawl and ship it will be of very great value for promoting midwater trawling.

Mr. Jakob Jakobsson (Iceland): As early as 1950 pelagic trawling began in Iceland for spawning cod but in spite of extensive trials in 1957 and 1958 we could not use this gear for catching herring. In 1959 we carried out extensive trials with an ordinary four-sided trawl with a head line of 20 metres. We used three sweeplines and followed the ideas of Dr. Schärfe of putting the real weight of hauling on the centre and side pieces through the middle line, having upper and lower sweeplines a little longer so as to give the trawl full opening. These three sweeplines were then connected to Larsson's phantom wing trawl boards and we always found them sturdy enough and they never failed to give good results. Lacking a netzsonde equipment, we found it difficult to judge the distance from the bottom and we concentrated on catching herring near the surface. In December 1959, and January 1960 we had good catches of herring during the night when the shoals were approximately 10 to 30 fathoms from the surface. We often had catches of 20 tons in a haul of 10 to 15 minutes. On two or three occasions we had catches of up to 40 tons, still working quite near the surface. At these depths we found that the Larsson wing trawl boards were good; we paid out five times the length of warps in relation to the estimated depth of the trawl.

In the following year commercial trawling was unsuccessful and the only reason that could be assigned was the different shoaling behaviour of the herring. Later, however fantastic success on these grounds was achieved by purse seiners with Asdic guided search and power hauling. They got higher catches—even as high as 150 to 300 tons per shot—and of course it was quite out of the question for midwater trawling to compete with that commercially. Looking back on the situation, however, what he found most disturbing was that when he calculated the density of the concentrations in relation to the volume of the sea water that the seines sieved, he found that with the midwater trawl they certainly got less than 10 and probably only 5 per cent of the herring they encountered. On those facts he thought they were certainly a very long way short of perfection with this gear, that is, provided those calculations were anywhere near to the truth.

Dr. A. T. Treschev (USSR): When fishing in midwater we have to deal with three dimensions and operate in space where the fish have more possibility of avoiding the trawl. that is why we have smaller success in midwater fishing. In fact in midwater trawling we have one problem: we must either have a big trawl and small speed or a small trawl and big speed. In catching each species of fish we must know the optimal of this parameter. An increase in vertical and horizontal scope can be obtained by hydrodynamic methods but the real problem was the behaviour of the fish. They had different types of trawlers which worked different trawls but they had more successful fishing with their light trawls on herring but it was not a constant success. One time they would have good fishing and another time bad fishing—it

depended on the concentration of the fish. That was why implements for measuring the parameter of the trawl and the fishing were very important.

Dr. F. McCracken (Canada): Experience with midwater trawling in Canada had been rather sporadic. A trawl had been developed on the West Coast of Canada and used occasionally more as a trawl just off bottom than as a midwater trawl. It did not compete effectively with the purse seine operation in that area. There had been some use of it as a trawl just off the bottom in the freshwater fisheries of the Great Lakes for smelt. There was however still some doubt as to how much better it was than the ordinary high-rising bottom trawl in that area. There were great difficulties in operating a midwater trawl and there must be a strong motivation to engage in it and their experience had been more or less in abeyance over the past 18 months.

Mr. J. A. Tvedt (UK): We have been pondering this problem and our solution is that we prefer to use a bottom weight and to try a four-cornered selvedge. We are trying to make the nets as small as possible and to use otter boards that are self-stabilising and automatic and we feel that by trying to increase the speed (with such records as we have of knowledge of the fish) we may be able to increase the catching rate to a comparatively good figure. From the discussions it is apparent that there is very little real knowledge about the actual behaviour of the fish so that we do not know what we are trying to do and whether it will lead to the result we want. There must be more knowledge of fish behaviour—that is the real answer to our problems.

Mr. D. L. Alverson (USA): Mr. McNeely's big net was designed to work in very transparent waters where fast swimming sub-tropical fish lived. We wanted some of them for biological purposes and the net was primarily aimed to catch them as well as with an eye on commercial practice. The philosophy behind it was that if we got a big enough net and if the fish did not react until he was well back in the net, there was a good chance of capturing it. From the point of view of the biologist the net was an evident success. They got a tremendous variety of fish including most of the high-speed ones. He acknowledged it had shortcomings in commercial application. There were difficulties in handling a four-door arrangement. But they should not preclude a net because of its difficulty. If a gear could catch fish, fishermen would learn how to handle it. Its success was dependent on the fish and it came back to the behaviour of fish to the gear and the geographical location in which they worked. There was a tendency to assume that because something was quite successful in one region it was applicable to another but that was not necessarily true.

Mr. Harper Gow: Thank you for that last remark. We have seen repeatedly that successful methods in one part of the world do not produce the same results in other parts.

Dr. Schärfe, commenting on Mr. Larsson's references to high-speed trawling, said high speed was not necessarily essential as recent experiences demonstrated. Actual commercial trawling on non-spawning herring was being carried out in winter as well as summer in the North Sea both by pair trawls and one boat trawls and they operated at speeds 3·5 and 4·2 knots. Practical experience showed that higher speeds did not necessarily increase catches—on the contrary, but all experience must be restricted to the conditions appertaining. In connection with floats, some of the sophisticated types of equipment for midwater trawls caused the nets to act something like parachutes so that weights and floats were mainly needed for keeping the gear clear when shooting. There was no doubt that Mr. Larsson's devices performed well. Experience showed, however, that these devices were somewhat difficult to handle over the rail, particularly the lower devices attached to the footrope. In connection with Mr. Larsson's proposal for new gear with a small opening and large meshes and part of the net being replaced by guide lines kept in shape by paravanes—that was theoretically interesting and he expected it would work under certain conditions. That they would have to find out. He was not certain it would work for herring and there might also be operational difficulties when shooting and hauling As to the netzsonde he personally believed that the advantages provided were such that the difficulties of handling the cable were more than compensated for.

Mr. S. O'Meallain (Eire) asked for information concerning the hauling of the cable on the netzsonde with which they had had difficulties.

Dr. Scharfe: You have put your finger on the weak spot in the system. The way of handling the cable depends on its length and the size of the boat. On small boats cables up to 300 metres in length are handled by hand winches. On the larger ships they handle the cables with a special electric winch with pushbutton control. There might be four different stages of power operation of the winch depending on whether they were shooting, hauling or towing. These winches had reached a stage of development where they worked very satisfactorily. Special cables are used, having a breaking strength of about 1 to 1·5 tons. There are two types—one has a separate steel wire cable to carry the load and two copper cores and this type is not so advantageous because it is difficult to repair and the copper cores may also break under stress due to twisting. The better type is the co-axial type where the central steel wire carrier at the the same time is used as one of the conductors. This is very well insulated and covered by a layer of braided copper wire as second conductor, which again is well insulated. This complete cable has a diameter of 12 mm and the breaking strength is quite sufficient for one boat trawling. We have never experienced any breaks during actual trawling. Occasional breaks during shooting operations have been due to lack of experience. For pair trawling higher breaking strength is needed because of the higher towing resistance of the cable, particularly when changing course. The combination drifter-trawlers who operate midwater pair trawling all have this equipment. The skippers definitely prefer this equipment for successful fishing although they grumble at the difficulties. An important point for the successful operation of the cable was the position of the winch and particularly of the small davit or gallows leading the cable overboard, so that the chafing of the cable on the ship's side is prevented. It was best to have these davits as far aft as possible. The connection of the cores of the cable to the recorder unit goes through rings with brushes on the axis of the winch. Repairing of the cable was very easy as there were good types of insulation tape available which were absolutely waterproof and could be put on very quickly.

Mr. McCracken (Canada): Our best success with midwater trawling is on the East Coast working in the winter months, for small herring of sardine size. Part of that success is due

to the transducer on the headline. On the West Coast there are about five smaller vessels working and they achieve their best success when the herring are close to the bottom. They do not use a headline transducer. Recently, they have been using some monofilaments in the forward part of the trawl and although not thoroughly tested yet this did offer some increased success. In Canada they were designing a small research vessel to investigate the feeding of salmon in the high seas and they were contemplating designing a triangular mouth trawl but no details of this were available yet.

Mr. J. Verhoest (Belgium): We started one-boat midwater trawling in 1959 fishing with a two-panel net for herring on the Sandettie grounds. In 1961 and 1962 those experiments were continued on the Smalls—grounds between England and Ireland. Further experiments were carried out with a Netherlands research vessel. For the latter experiments a Grouselle net was used for the Dogger Bank. During last winter different types of one boat midwater trawls were tried out along the Belgian Coast for commercial sprat fishing.

The main results of their investigations could be summarised thus: on the Smalls, using an Engel net, the results depended on finding high swimming herring schools which was helped by sonar and information from other vessels. In one haul they took 15 tons and in two days fishing they got 55 tons. Their opinion however, was that midwater trawls could only be regarded as complementary to a bottom trawl. Both gears should be carried. In the English Channel the catches were very poor in relation to the two-boat midwater trawl.

On the Dogger Bank trip with the Grouselle net they got one bucket of herring. This net had very small meshes for herring and was constructed of heavy twines. Otter boards were used which lifted the net off the bottom without changing the position of the point of attachment to the warps. The handling of this gear was more complicated than that of the Engel net especially in shallow water.

In the case of sprat fishing two-boat midwater trawling was more successful than one boat operation. They found that with their Engel net it was possible to catch herring in deep water but that the catches in shallow water with the same net were rather poor in relation to those of two-boat midwater trawls. To solve this problem the two research ships mentioned would also be equipped with a two-boat midwater trawl. This could easily be done on a side trawler. They would do it in the following way: on the starboard side they would have a herring bottom trawl, on the port side a one-boat midwater trawl and on the stern a two-boat midwater trawl. Much more needed to be found out about fish behaviour but their investigations into one-boat midwater trawling would continue.

Dr. Heinsohn (Germany): When conditions require it, it can be advantageous to change quickly from bottom trawling to midwater trawling. Then the connection of the cable to the transducer creates problems particularly on the bigger sterntrawlers when the net is drawn up on the slip deck. In that case the cable has to be run in some way from aft to forward on the slip deck. On a few boats we have found that the cable could be led from the aft bipod mast and that caused us to abandon the idea of having the two gallows connected by a bridge. Now we favour just two gallows posts to enable us to have a better run with the cable forward when the net is on the deck. Another point is that the change between bottom trawling and midwater trawling can occur quite often and should be easy to do. Therefore we experimented in adapting our aft gallows so that the boards should not be changed because changing of the boards is a major operation. The idea we are trying at the moment is that the boards for the bottom trawl in stern trawling should be on the outside of the vessel. The first experiments in this direction were quite successful and we think we can improve the whole thing. But on most vessels the winch with the cable automatic tension device should not be too far away from the bridge or should be in view of the skipper so that he can act quickly if anything goes wrong.

Mr. D. S. Howard (UK): We have made special mid-water nets for sprats. One little net used on a 45 ft boat (80 horse power) caught as much sprats as caught by two boats. With the same net he himself tried bottom fishing from Fleetwood and got good results. It was made of two panels with wedges at the sides. Since then, he had made 12 nets of that kind for Scotland where they were being used in seiners. The net was also to be used at Killibegs.

Mr. M. S. Parsey (UK) asked for information as to the type of material used in constructing the midwater trawls.

Dr. Schärfe: In Germany for midwater trawls so far nylon knotted netting is being used. We use normal nylon 6, because in midwater trawls where twine is made as thin as possible a rather high amount of elasticity is needed to equalise the differences in the stress in the netting which may lead to tears. To attain this elasticity even spun nylon is used for attaching the webbing to the ropes. Twines of Td 210/60 in the front part decreasing to Td 210/33 in the aft belly have given satisfactory results. Knotless netting had been tried but results are not fully known yet.

Mr. L. Libert (France): On the subject of high and midwater trawling, using a single trawler, the Scientific and Technical Institute of Sea Fishing Laboratory at Boulogne-sur-Mer carried out a series of trials on small scale models following a definite technique outlined in bulletins Nos. 79 and 92 in *Science et Pêche*. These began in 1959. For trawling, both on the bottom and midwater, these trials were carried out with a Vinge type trawl (two unequal panels) and with both two and four panels (equal) trawls.

These truly extensive trials were controlled by netzsonde and carried out both by boats belonging to the Institute (fisheries research vessels) and other boats in collaboration with the Institute. In the course of these trials many different kinds of equipment were tried out: (a) a system for purely pelagic fishing with long legs and boards of the ordinary type with modifications or special boards; and (b) two systems for midwater trawling. In the latter case, first, with ordinary boards with long legs for trawling with nets of two unequal panels and, secondly, with ordinary boards with arms above grafted to the trawl-cables and in front of the boards—this system being nearly similar to the 'Icelandic Breidfjord mounting'.

The observations made during the course of these trials lead to the identification of several conditions favourable to this type of fishing: (a) detection of schools of fish away from the sea bed; (b) the minimum speed of trawling necessary for catching certain species of fish; and (c) trawling above certain minimum depth of water to avoid the dispersal of schools caused by the noise of the propeller. In every case where these conditions have all been followed the results obtained during these trials were very satisfactory.

As to the fish caught in the course of these trials: in 1961, off the coast of the Vendée, the Roselys, a fisheries research

vessel belonging to the Institute, of 120 hp motor, when midwater fishing with a trawl with two equal panels—secured an average hourly catch of 450 kgs (sprat and anchovies) and a best catch of 3 tons.

Again in 1961, off Boulogne, the Notre Dame du Carmel, an Etaples trawler of 250 hp: when semi-pelagic trawling using a trawl with two unequal panels and under normal fishing conditions—secured an average daily catch of 1-2 tons (sprat, whiting and cod). Under the best conditions the catch's weight and value were 50 to 100 per cent above that of trawlers working the same grounds with an ordinary trawl. By the term semi-pelagic is meant midwater trawling close to the bottom and by pelagic, trawling in midwater.

In 1962, off Lorient, using the oceanographic vessel, Thalassa, and operating midwater trawling with trawls of 2 and 4 panels (equal) an average hourly catch of 600-1,500 kgs (sprat and sardine) was obtained. The results were less good in depths of less than 30 metres.

In 1962, the same vessel, Thalassa, using a midwater trawl with two equal panels in the Gulf of Maine, got a maximum hourly catch of 7 tons of herring. In 1962, in the Mediterranean, the trawler Sainte Madeleine of 300 hp when motor fishing from La Ciotat, and midwater trawling with a trawl with 2 unequal panels got a very useful catch. The best result obtained was 5 tons in less than half an hour (sardines anchovies and sprat).

In the case of commercial fishing the records of usage and catch of midwater trawling show that about 20 French trawlers of from 150 to 1,300 hp during favourable periods have used midwater trawling methods with a single boat. At present this method of trawling is practically wholly confined to semi-pelagic trawling with the methods indicated above: long legs or the Breidfjord mounting, and with ordinary boards in the two cases.

As to the catches made in 1962, four trawlers of 1,300-1,400 hp from a Boulogne fishing company, equipped with a trawl with 4 panels obtained useful results in fishing for herring in the Smalls region during the period between August 1 and September 15. The catches recorded were two to three times better than those of boats using the ordinary bottom trawl. The best catch recorded was about 20 tons.

About a dozen trawlers from Boulogne of between 500 and 1,400 hp are now equipped sometimes with a trawl with 4 equal panels, while others have a 2-panel (unequal) trawl. Many of these vessels have obtained good catches of herring and whiting.

In Brittany the first trials of semi-pelagic trawling with a single boat took place in 1962 at the commencement of the mackerel season. Many vessels, equipped with a 2-panel (unequal) trawl, obtained during the first week results twice or three times those of trawlers using bottom trawls.

The results obtained in both pelagic and semi-pelagic trawling in the course of the trials conducted by the Institute have thus demonstrated that there are possibilities of using different types of midwater trawls from a single boat of a type adapted to the fishing conditions.

The results obtained by commercial fishing boats, even under the present limited availability of these trawls, justifies the further use of this equipment (two bulletins [Nos. 95 and 110] have been issued by the Institute on this subject.)

Mr. H. Kristjonsson (FAO): In South Japan they have developed especially over the last few years successful commercial midwater trawling for big-sized shrimp in the East China Sea. Fishing is done on the bottom, just off the bottom, and in midwater in depths of up to 70 metres on most of the grounds and the shrimp schools rise from 10 to 40 metres off the bottom in winter months, and are detected by high frequency (200 kc) echo sounders, which are standard equipment for this fishery. One echogram from a high frequency sounder showed one school of big shrimp (*Penaeus orientalis Kishinorsye*) with an estimated thickness of 35 metres and a length of about 480 metres.

The trawlers worked from December to March and they generally used nets fitted with cable netzsonde. When he was there six or seven months previously he made a special point of asking the fleet managers and the men in the repair shops what trouble they had in handling the cable. Their answer was that there was some trouble but it was well worth it. Some of the echo sounding companies in Japan were also selling cableless depth indicators which, however, did not do the same job as a netzsonde. They only gave the depth of the headline and did not show anything else. Only the cable units gave the full information. The nets were very big with headlines of 40 to 45 metres and footropes of 50 to 55 metres. The boats doing one-boat trawling were 300 to 400 tons with engines of 750-850 horse power. Similar nets, but bigger, were used by two-boat trawlers of some 350 horse power each. In this case the headline length would be up to 80 metres. The nets were invariably made of polyethylene knotless of the Japanese two-strand twisted type and were coloured black. The bigger companies had standardised on that type. One-boat trawlers all used high curved otter boards of the Suberkrub type. The boards were 3·2 metres high and 1·6 metres broad. They were now built of steel but formerly had been of steel and wood construction. They had gone completely over to high curved otter boards. They had given up the conventional flat rectangular ones. Also on the big Japanese sterntrawlers they used curved otter boards of the Suberkrub type.

Dr. Schärfe, in summing up, made these points: Under certain economic conditions there might still be scope for midwater trawling even where purse seining was practised. Mr. Verhoest's Belgian experiments showed that lighter types of vessel could operate successfully but catches were not always reliable. In shallow water pair trawling was normally considerably more successful than one-boat trawling. This was to be expected because a single boat had to go over the school and its wake might disturb the fish. One possibility of avoiding this, namely to have one otter board considerably larger in order to get the trawl outside the wake of the propeller was tested with unsatisfactory results. Dr. Heinsohn's comments on the attempts of fitting big stern trawlers for both bottom and midwater trawling indicate the growing interest of trawler owners and suggest that interesting results might be forthcoming next summer. His own remarks about fitting netzsonde cable etc., related only to side trawlers. On the siting of the cable winch, he could say that on stern trawlers they had already centralised winch control with success so that the man in charge of the other winches should also operate the cable winch. On stern trawlers the winch for hauling the cable must not necessarily be at the stern. On the new German research vessel it was being installed very close aft of the centralised winch control.

King Crab Pot Fishing in Alaska

Abstract
The king crab *Paralithodes camtchatica* fishery of Alaska has developed spectacularly during the last five years. In 1962 United States fishermen, operating a fleet of over 200 vessels, produced 50,000,000 lb of king crab valued, to them, at $5 million. King crabs vary in commercial size from 7 to 25 lb, with an average weight of 10 lb and a spread of 3½ ft between leg tips. The whole legs are frozen in the shell or the meat is extracted and canned or frozen. Although various types of gear, such as tanglenets, trawls and pots have been used since the establishment of a sustained United States fishery in 1947, nearly all king crabs are now caught in pots. Pots vary in size from six ft diameter round pots to 7×7×2½-ft square pots, weighing 250 lb each; the latter type is now used on most of the large king crab vessels. The seven-foot pots are constructed of welded mild steel round bar, usually covered with 0·048-inch diameter soft stainless steel wire woven in five-inch bar mesh. Nylon netting is now being used by some fishermen in place of stainless steel. A tunnel at each end slopes up to 40 ×7½-inch opening. The pots are baited with frozen herring. Pot lines are of ⅝-inch diameter nylon and polypropylene, in 30 fm sections, to fish in depths from 20 to 150 fm. The line is buoyed with one or two 20-inch pneumatic plastic bags. The pots are set individually, usually within 10 miles off the coast in a straight line or "string" to facilitate location. Depending on the area, from 30 to 80 pots per vessel are used and hauled each day, weather permitting. An average of 50 crabs per pot is considered good fishing, and 100 crabs per pot is considered an excellent catch. Vessels range in size from 40 to 150 ft and the majority were built originally for halibut and salmon fishing. All of the larger vessels are equipped with seawater tanks in the hold since crabs must be alive up to the time of processing. The fishing area of the smaller vessels is limited as seawater tanks are not feasible for them and the crabs will live only about 12 hrs out of water, even if kept wet with salt-water spray. Pots are hauled on winches with warping heads at speeds up to 300 ft/min. A hydraulic drive is desirable since maximum line tension must be limited to prevent breaking pot lines when sudden surges occur when hauling in heavy seas. Even though pots can be hauled and reset at the rate of 6 to ten per hour, ways are continually being sought to speed-up the operation. The most recent device is a hydraulically-driven V-grooved sheave mounted on a davit or boom. Speed, direction and maximum line tension of the crab pot and topping and swinging to bring the pot aboard are controlled by a console located adjacent to the bulwarks.

La pêche a la nasse du crabe royal en Alaska

Résumé
Au cours de ces cinq dernières années, la pêche du crabe-royal *Paralithodes camtchatica* s'est développée d'une façon spectaculaire en Alaska. En 1962, aux Etats-Unis, une flotte de 200 bateaux de pêche a produit environ 23,000 tonnes de ces crabes, d'une valuer de cinq millions de dollars. Le poids de ces crustacés varie de trois à 11 kilos, avec une moyenne de 4·5 kilos et la distance entre les extrémités des pattes est d'un mètre environ. Les pattes sont congelées dans la carapace ou bien, la chair en est extraite et mise en boîte ou congelée. Bien que divers types d'engins tels que filets à crustacés, chaluts, aient été utilisés, depuis l'établissement aux Etats-Unis d'une pêche organisée, presque tous les crabes sont capturés à la nasse. La taille des nasses varie de 1·80 m de diamètre pour les rondes à 2m × 2m × 0·75 m pour les carrées, chacune d'elles pesant 110 kilos. Les nasses carrées sont plus particulièrement utilisées par les grands bateaux. Elles sont construites de barres d'acier léger, recouvertes d'un grillage d'acier inoxydable de 1·2 mm de diamètre formant des mailles de 12 cm. Quelques pêcheurs utilisent maintenant, à la place du grillage d'acier, du filet de nylon. Le tunnel construit à chaque extrémité se rétrécit jusqu'à une ouverture de 120 cm×18 cm. Les nasses sont appâtées avec du hareng congelé. Les lignes des nasses sont en nylon et polypropylène de 16 mm de diamètre, par sections de 55 m et pêchent à des profondeurs de 37 à 270 m. Les lignes sont allégées avec deux sacs pneumatiques en plastique, de 50 cm de diamètre. Les nasses sont placées individuellement, généralement à une distance de 10 milles de la côte, en droite ligne pour faciliter la localisation. Suivant la région, de 30 à 80 nasses sont utilisées par chaque bateau et elles sont halées tous les jours si le temps le permet. On considère que 50 crabes par nasse représentent une bonne pêche; 100 crabes, une pêche excellente. Les bateaux ont de 12 à 45 m de long et la plupart ont été construits à l'origine pour la pêche au saumon et au flétan. Tous les grands bateaux sont équipés avec des réservoirs à eau de mer, les crabes devant être vivants au moment de leur traitement. Pour cette raison, les lieux de pêche pour les petits bateaux sont très limités car ceuxci n'ont pas de réservoirs et les crabes ne peuvent vivre au-delà de 12 heures hors d l'eau, même s'ils sont arrosés. Les nasses sont halées par des treuils, à une vitesse de 90 m/min. Pour éviter que sous l'effet de la houle, les lignes se cassent, il est désirable d'avoir un entraînement hydraulique pour les treuils. Bien que les nasses puissent être halées et remises à l'eau à une cadence de six à 10 par heure, on recherche toujours des moyens pour accélérer les opérations. Un de ces moyens consiste en un rouleau de coupe en V, actionné hydrauliquement et monté sur un bossoir. Les vitesses, direction et tensions maximum sur les lignes des nasses aussi bien que le halage et le pivotement pour prendre la nasse à bord, sont contrôlés par un table de manoeuvre situé dans le pavois.

by
R. F. Allen

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Pesca del centollo de Alaska con nasas

Extracto
La pesca del centollo de Alaska *Paralithodes camtchatica* se ha desarrollado espectacularmente en los últimos cinco años. En 1962 pescadores de los Estados Unidos a bordo de más de 200 embarcaciones capturaron 50 millones de libras de cangrejo, que les representó un ingreso de cinco millones de dólares. El centollo comercial pesa de 7 a 25 lbs con una media de 10 lbs y tiene una envergadura de 3·5 pies entre los extremos de las patas. Estas se congelan enteras o se les extrae la carne que se enlata y congela. Aunque desde el establecimiento en 1947 de una pesquera constante de los EUA se han empleado varias clases de artes como el de enredo y el de arrastre, y nasas, casi todo el cangrejo se pesca en la actualidad con nasas. Las dimensiones de éstas varían; las redondas tienen un diámetro de seis pies y las cuadrades son de 7×7×2·5 pies y un peso de 250 lbs. Las últimas se emplean actualmente en casi todos los barcos cangrejeros grandes. Las de ocho pies son de barra de acero suave soldado y normalmente se cubren con una tela metálica de acero inoxidable flexible de 0·048 pulgadas de diámetro, con mallas de cinco pulgadas entre nudos. En la actualidad algunos pescadores usan red de nylon en vez de acero inoxidable. Una abertura en cada extremo conduce hacia arriba hasta entradas de 40×7·5 pulgadas. Las nasas se ceban con arenque congelado. Los cables son de nylon o polipropileno de 5/8 pulgadas de diámetro en secciones de 30 brazas. Se da flotabilidad al cable con uno o dos neumáticos de material plástico. Las nasas se calan individualmente por lo general a menos de 10 millas de la costa y en línea recta para facilitar la localización. Según el lugar, cada barco usa de 30 a 80 nasas que levanta a diario si lo permite el tiempo. Un promedio de 50 centollos por nasa se considera una buena pesca y de 100, excelente. La eslora de los barcos varía de 40 a 150 pies y la mayoría se construyó originalmente para pescar hipogloso y salmón. Todos

los barcos grandes están equipados con tanques de agua de mar para almacenar los centollos, que tienen que estar vivos hasta el momento de la elaboración. La actividad pesquera de los barcos más pequeños está limitada porque no pueden equiparse de tanques de agua de mar y los cangrejos sólo viven unas 12 horas fuera del mar aun si se mantienen húmedos con pulverizaciones de agua. Las nasas se izan con maquinillas de tambores a velocidades hasta de 300 pies/min. Conviene emplear una transmisión hidráulica porque la tensión máxima del cable hay que limitarla para impedir que se rompa cuando el barco se mueve violentamente en mar gruesa. Aunque las nasas se levantan y se calan de nuevo a razón de 6 a 10 por hora, continuamente se estudia la manera de acelerar la maniobra. El dispositivo más moderno es una roldana con garganta en V accionada hidráulicamente y montada en una pluma o botavara. La velocidad, dirección y tensión máxima del cable de la nasa y los movimientos de la pluma para materla a bordo se regulan desde un cuadro colocado junto a la regala.

IN Alaska the king crab fishery is the fastest growing commercial fishing industry. In terms of value the catch taken on the grounds from Prince William Sound to the Aleutian Islands is second only to salmon for the state of Alaska. The industry has developed spectacularly in the last five years to an annual catch of 50,000,000 lb (with a value of $5 million to the fishermen) in 1962. A fleet of over 200 vessels is presently engaged in this fishery.

The king crab (*Paralithodes camtchatica*) varies in commercial size from seven to 25 lb, with an average size of 10 lb and a spread of $3\frac{1}{2}$ ft between leg tips. Only the meat in the legs is recovered; the whole legs are frozen in the shell or the meat is extracted and canned or frozen.

Although commercial harvest of king crab by United States fishermen began in the 1930's on a sporadic basis with pots, a sustained fishery did not get underway until 1947, when tanglenets, trawls and pots were used. At that time trawling predominated. The first experiments with pots did not produce promising results, and tanglenets required considerable labour. Subsequently pot designs have been improved to the extent that virtually all king crabs are now caught in pots. The success of this fishery can be attributed to the efficiency of modern king crab pots and to the methods of handling pots with relatively few men.

Handling crab pots

The crab fishermen's experience in the location of setting pots has been by trial and error. Electronic detection equipment is not presently in use for locating crabs prior to setting the pots. Recording type fish finders do not detect king crabs on the bottom except in moulting season when crabs bunch together. Crab pots are set individually with a line and buoy in coastal waters, usually within 10 miles of the coast. In order to facilitate the location of the pots they are generally set in a straight line or "string". Considerable care is taken to fix the position of the string of pots. As the buoys are sometimes out of sight of land, a radar reflector buoy is anchored at the end of the string. Each buoy is numbered and its location recorded when set. State of Alaska fishery regulations limit vessels to 30 pots in the Kodiak and Cook Inlet areas, but in more remote areas where no legal limit is in force 50 to 80 pots per boat are often fished.

Frozen herring is used as bait. It is placed in a perforated metal container or bag attached in the centre of the pot. The pots are launched off the side of the vessel in water of from 20 to 150 fm in depth. Since the tidal currents are quite strong and the drag on the pot warp is considerable, the buoys must be large enough to remain above the surface. Fishermen are using two 20-inch diameter pneumatic plastic buoys similar to Scandinavian longline fishing floats (Fig. 1). Weather permitting, the pots are hauled every day.

Fig. 1. Retrieving a crab pot buoy. Small auxiliary buoy facilitates recovery.

Several methods are employed in hauling the pots aboard. Inasmuch as many of the crab boats are also used for salmon seining during the summer, they are generally equipped with gypsy winches. The pot line is led over a davit mounted snatch block to the gypsy head and is tailed and coiled on deck by the fishermen. When the pot reaches the surface, a heavy fall from the main boom is hooked to the rope bridle and the pot is then swung on board and set across the bulwark and the hatch coaming (Fig. 2).

A number of vessels are now equipped with a V-grooved hydraulic pot hauler which is mounted on a davit or boom (Fig. 3). Where a power boom is used it is possible to lift the pots on the deck with the pot warp; however, some fishermen prefer to use a safety line from the end of the boom to minimise the risk of breaking the pot warp when the pots are loaded (Fig. 4). The top of the pot hinges open and the crabs are dumped onto the

Fig. 2. Pots are set between hatch and bulwark. Fishermen using gypsy on longline-type gurdy, as this vessel also fishes for halibut.

deck; then the pot is rebaited and launched overboard. The crabs are sorted and male crabs with a shell width greater than seven inches are put into the circulating water tank in the hold of the vessel. Small males and all female crabs are returned to the water. In a good day's fishing pots can be hauled at the rate of 6 to 10 an hour, depending on water depth and sea conditions. An average of 50 crabs per pot is considered good fishing, and 100 crabs per pot is excellent. A 7 × 7-ft pot containing 294 8- to 10-lb crabs has been reported.

The crabs are held in circulating water tanks and delivered to processing vessels or shore plants for freezing or canning of the leg meat. Many of the smaller vessels have not been equipped with seawater tanks and are therefore restricted in their range. King crabs can

Fig. 3. Hydraulic crab pot hauler on boom for positioning pots on deck.

Fig. 4. 7 × 7 ft pots brought on board with a chain fixed to boom end after being raised to water surface with hydraulic pot hauler.

live for about 12 hrs out of water if they are kept wet with salt water spray. Crabs must be alive at the time of processing; therefore circulating water tanks are becoming a necessity as the vessels venture farther from the plants.

Vessel types

Vessels employed range in size from 40 to 150 ft. No new vessels as yet have been constructed specifically for king crab pot fishing; the majority have been adapted from salmon and halibut fisheries of the north Pacific. The general trend in recent years has been toward larger vessels that can operate in more remote areas, transporting all their pots on board at one time. The hazards of winter fishing in severe weather conditions, with vessels loaded to capacity with water in the tanks, has resulted in some loss of life and vessels, and has hastened the trend toward larger boats.

A great deal of experimentation in equipping vessels of all types has centred around obtaining a balance of the following desirable characteristics:

(a) Pilot house located so that the helmsmen can readily observe the fishermen and manoeuvre the vessel with fingertip engine and steering controls to each pot buoy.
(b) Large deck space for storing the pots. Outside of the areas where state regulations permit only 30 pots, the larger vessels have some advantage

in their ability to carry more pots and travel into relatively unfished areas. The small boat, which must make several trips to a new fishing ground in order to transfer the pots, loses considerable fishing time.

(c) A stable working platform. The ability of the larger vessels to haul crab pots in rough weather is a most important factor in this area where heavy seas are experienced.

(d) Ability to handle heavy loads of seawater in tanks. A detailed study of stability and freeboard is most important in view of the steep seas, high wind and icing conditions encountered during the winter king crab fishing. Adequate stability must exist in both light and loaded conditions and during flooding of the tanks.

The fishing vessel *Jeanette F* (Fig. 5) is typical of the majority of recent additions to the king crab fleet. This vessel is equipped with a hydraulically actuated boom

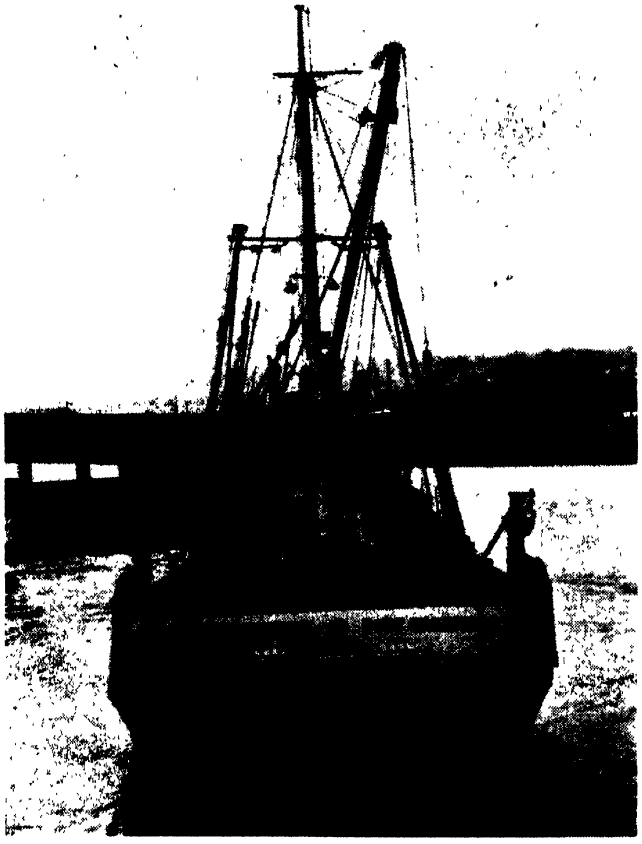

Fig. 5. Typical crab boat. 72 × 18 ft 6 in. Carries trawl gear as well as 30 to 40 pots.

and pot hauler. Controls for speed and direction of the pot hauler and for topping and slewing the boom are located adjacent to the bulwark amidships. The vessel is also equipped with trawling gear; however, this is seldom used for king crab.

Most of these vessels are equipped with outrigger fin stabilisers for rough weather fishing. The 20-ft poles mounted port and starboard hinge outboard to an angle of approximately 35° above horizontal. Fin stabilisers hang from the ends of these poles approximately 20 ft below the surface. They are heavily counterweighted so that they have a continuous tendency to dive. This type of stabiliser is quite effective in heavy weather. (Figs. 5 and 6 show the poles extended and stowed.)

Typical of the smaller type of inshore crab fishing boats is the 46-ft steel combination salmon purse seiner (Fig. 6). The hold consists of a single tank of 870 ft³

Fig. 6. Small steel crab and salmon seining boat. 46 × 15 ft with stabiliser poles and fins used in rough weather.

in volume. It has a capacity of approximately 1,760 10-lb crabs. The deck arrangement is typical of the Alaska purse seiners, with a two-gypsy winch used to haul pots. In the latest steel crab vessel designs the hold tank does not extend the full beam of the vessel but is limited in width by outboard voids or fuel oil tanks on either side so as to reduce the loss in stability due to free surface in the tank, should it be necessary to fill or empty the tank at sea. During normal operations these tanks are completely full into the hatch trunk. The water level is 1 ft below the bolted down hatch cover flowing overboard through a screened discharge pipe. A small 2 × 2-ft hatch for loading crabs is located in the starboard side of the hatch cover (Fig. 3). When unloading the crabs from the vessel with buckets, the entire hatch cover is removed.

Fig. 7 shows a tender type vessel, twin screw, which was converted for king crab fishing. The conversion included two large steel tanks of 1,280 ft³ each in volume, steel bulwarks port and starboard, a circulating seawater system for the tanks, and pot hauling equipment. This vessel has a capacity of 5,000 king crabs and, because of its extreme beam, is ideal for carrying pots on deck. This type of vessel is remarkably well suited to this service.

The most recent and largest king crab fishing vessel in Alaska (Fig. 8) was converted from a naval landing craft 159 ft in length. This large vessel operates with a total crew of four men. The two tanks have a total capacity of 6,780 ft³. She is reported to carry 15,000

Fig. 7. Alaska salmon tender converted to a crab fishing vessel. 86 × 28 ft.

8-lb crabs. The pots are hauled forward on the starboard side, with a line led over a block on the end of a short davit. A gypsy winch with one large diameter warping head for high speed and one of smaller diameter for slower speed and heavy lift is mounted on the starboard side forward (Fig. 9). The crab pot is brought to the surface and a fall from the main boom is attached to a bridle on the pot for hoisting it aboard. Each crab tank is equipped with an elevator consisting of a steel frame with netting covering the entire area of the tank and resting on the bottom. Cables from the four corners of the frame are led to the main boom cargo gear. When the crabs are being unloaded into containers on the deck, this elevator is hoisted so as to keep a layer of crabs at the level of the hatch coaming. This permits the crew to load crabs into hopper baskets directly at deck level without pumping down or entering the tanks. In using this system to raise the crabs in the tanks, the top opening must be the full width and length of the tank so that crabs are not crushed against the tank overhead.

Fig. 9. Hydraulic gurdy with 18 in diameter chrome-plated gypsy and auxiliary gypsy. The pot line is led over a davit-mounted block.

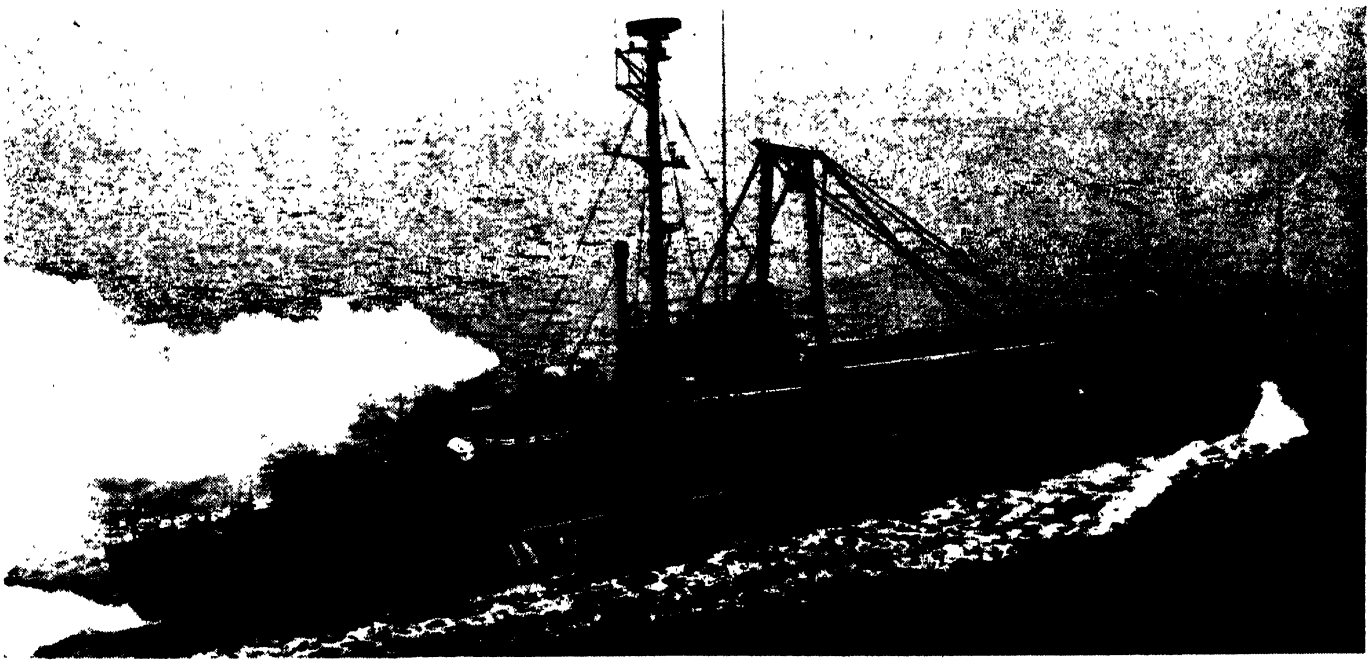

Fig. 8. Largest crab fishing vessel. 159 × 23 ft 3 in. Fishes 80 pots with a crew of four men.

Tanks

Crab fishing vessels are equipped with tanks consistent with the freeboard and stability requirement. Steel is the most common tank lining. As the fish holds of most existing vessels are sized for lower density fish and ice, the volume is larger than can be safely considered for the crab tank. Considerable care must be taken to analyse the effect of the weight of the tank and water on the trim and freeboard of the vessel. An inclining experiment is suggested to determine the stability of the existing vessel and to provide a basis for estimating the stability during the period when the tanks are slack and under full load conditions. Table I describes typical king crab vessels of various sizes and their respective tank volumes. The carrying capacity is approximately two 10-lb king crabs per cubic foot.

Table I.—Tank capacities of various king crab fishing vessels

	Gross Tonnage	Length Overall	Beam	Cu ft
Sunrise ..	129	86	22	2,760
Pacific Fisher	113	81	21	2,300
Falcon ..	43	46	15	900
Selief ..	178	86	28	2,400
Nordic	45	61	15	1,050
Pacific Pearl	61	68	17·4	1,430
North Beach	108	75·8	21·5	2,400

Consideration should be given, when designing crab tanks in wooden vessels, to providing adequate ventilation between the steel tank lining and the sides of the vessel. Rot in the wood is a constant problem and it is therefore suggested that the tanks be covered on the outside surfaces with an insulating sweat-resistant coating. The inside of the tanks are often coated with a coal tar water-base coating.

Water is circulated through a perforated pipe manifold located in the bottom of the tank and discharged overboard at a level 1 ft below the hatch coaming. The pumping capacity should be adequate to change the water in the tank each 20 to 30 minutes. Fig 10 shows the arrangement of a typical pumping system which is driven by a small auxiliary 8 hp diesel engine suitable for a small vessel.

Crab pot designs

The present trend is toward the 7 × 7 × 2½-ft square pot, which is now used on most of the large king crab vessels (Figs. 4 and 11). The smaller vessels are using the 6 × 6 × 2½-ft square pot, and six-ft diameter round pot (Figs. 2 and 12). The square pot is more popular because it can be stored more easily on deck and has a greater capacity for the same overall dimensions. A seven-foot pot weighs approximately 250 lb, has a life expectancy of five years, and has an average value with line and buoy of $250. A 7 × 7 × 2½-ft pot has an internal volume of 104 ft³. Some of these pots have contained over 200 crabs with a total weight of 2,200 lb.

These pots are constructed of welded mild steel round bar, one-inch diameter for the bottom bars with three-quarter-inch diameter vertical and top frame bars. The tunnel and the door are framed with half-inch diameter round bar. The majority of the pots are covered with 0·048-inch diameter soft stainless steel wire, woven in five-inch bar length mesh. On each end a tunnel slopes up to the horizontal opening at an angle of 35 to 40°

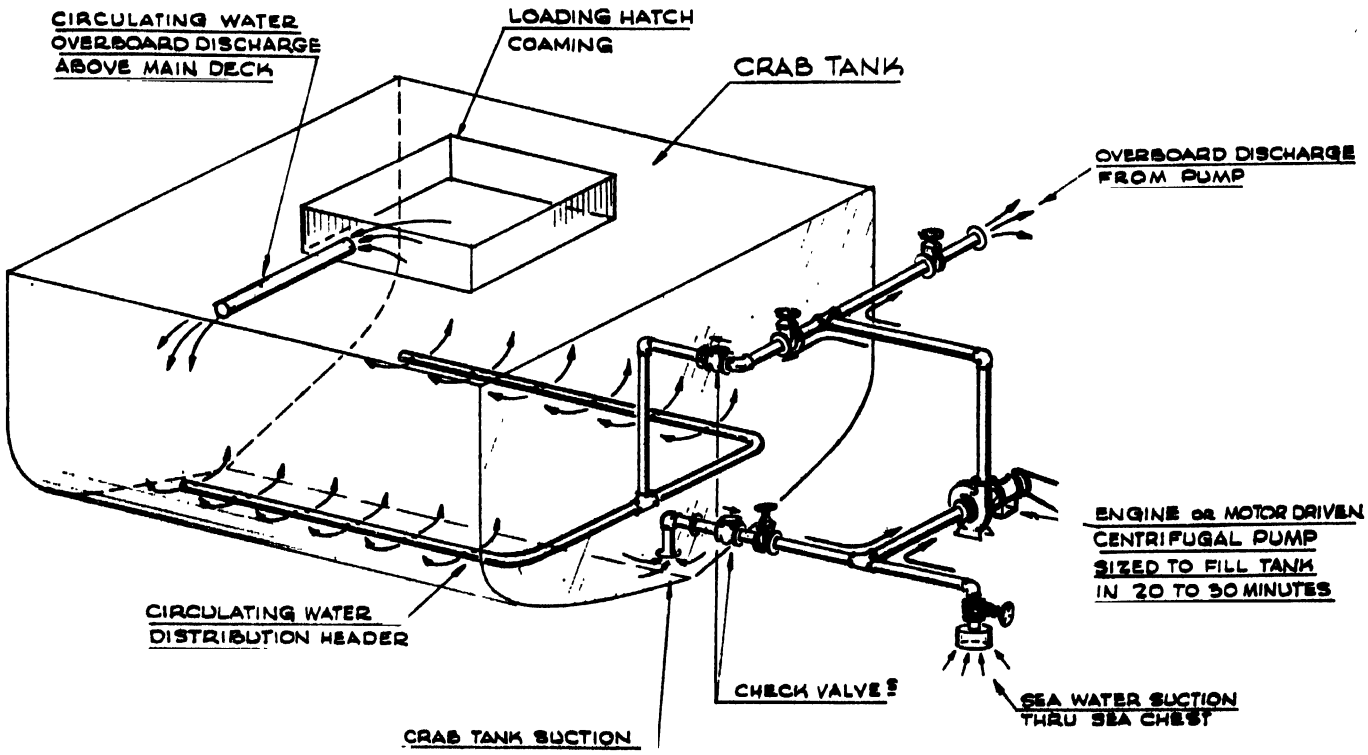

Fig. 10. Typical crab tank sea-water circulating system.

Fig. 11. 7 × 7 ft pot coming aboard. Note roller on gunwhale.

This section of the pot is woven with two-and-a-half-inch bar length wire mesh. Some fishermen are now using nylon netting. This requires a double frame designed pot, with the netting hung on inside bars which are protected from chafe of the hanging (see Figs. 4, 11, and 13). The nylon netting covering the top, sides and bottom is nine-and-a-half-inch stretched mesh, 10/72 thread. The tunnel is three-and-a-half-inch, 10/72 thread netting.

The tunnel design is a compromise between the reduction in volume of the pot and an attempt to reduce the slope of the ramp and provide an opening which will discourage the crabs' escape. The opening is almost horizontal, 40 × 7½ in. In areas of heavy fishing the pot openings are often reduced to 30 in in width to increase the internal volume. No trip mechanism or triggers are used to prevent escape.

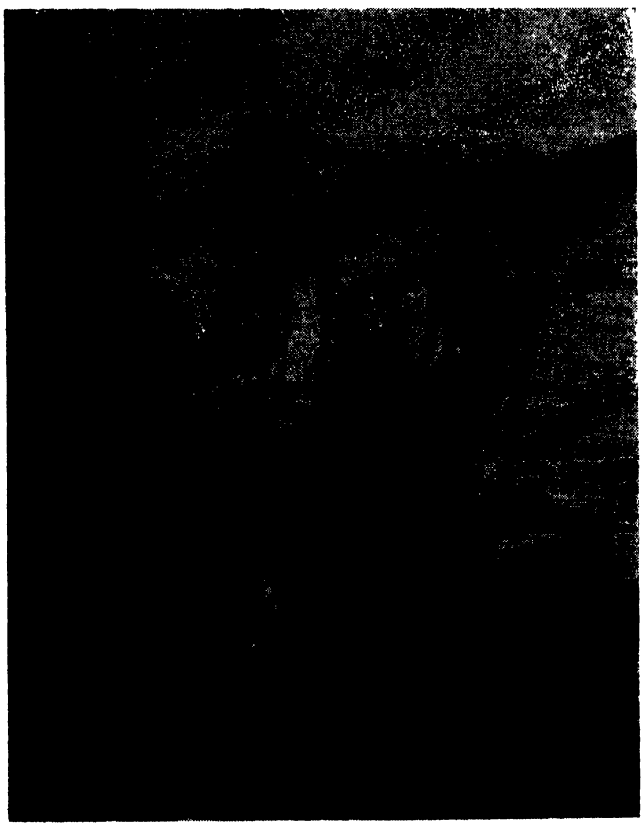

Fig. 12. 6 × 6 ft pots hoisted on board with falls from the main boom attached to a bridle on the pot.

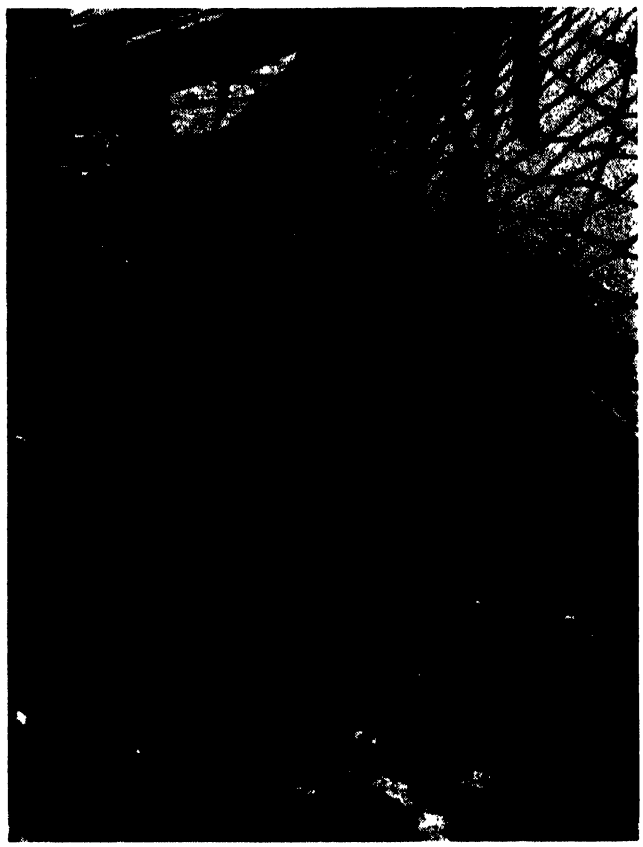

Fig. 13. Tunnel design on 7 × 7 ft pot.

Other configurations have been introduced which enable the pots to be stacked one inside the other, but to date none of these has come into popular use. It is possible that, as practicable mechanical means become available to handle larger pots, the size will increase.

Lines and buoys

Pot lines generally consist of 30-fm lengths of ⅜-inch diameter nylon and polypropylene. As the depths vary, these lines are tied together to lengths sometimes greater than 150 fm. Since polypropylene line will float, a 30-fm section is generally attached directly to the pot to minimise the possibility of the line becoming wrapped round the pot. Nylon is used at the surface since it is desirable to have the line sink vertically from the buoy to minimise the chance of its being cut by the propellers of passing vessels.

The typical buoy attachments consist of one or two 20-inch diameter pneumatic plastic bags, the same as those used in longline fishing. A two-fm line with a light float is attached to the buoy to facilitate retrieving (see Fig. 1).

Hauling devices

The most common pot hauler is a gypsy winch, already present on most crab vessels because they have been converted from salmon purse seining. A modified purse winch is shown in Fig. 9. This 18-inch gypsy produces a speed of 300 fpm and a line pull of 2,500 lb. It is hydraulically driven and has a maximum of 23 hp. Hydraulic drive is desirable so that the maximum line tension can be limited. This is almost a necessity when hauling in rough seas so that a sudden surge of the vessel will not break the pot lines (Lerch, 1963).

The most recent device introduced for crab pot hauling is a hydraulically-driven V-grooved sheave which has a hauling speed of 300 fpm and a line pull of 1,600 lb (Figs. 3, 4, 5, and 7). A stripping mechanism in the form of a wedge laid in the bottom of the crab block sheave prevents backlash. Small fairlead blocks guide the line onto the sheave. The latest design has an additional fairlead sheave so that the line will remain on the sheave when the knots ride over the groove. The deep wedging action of the sheave grips the line so that it is not necessary for the fishermen to put tension on the line coming from the block to prevent slipping. The slack line is merely coiled on the deck as it comes from the crab block. Speed, direction and maximum line tension of the crab block and topping and swinging of the boom are controlled from a console located adjacent to the bulwarks. At the beginning of the operation, the boom is lowered to a position that enables a man to insert the line over the sheave. Throughout the hauling, the boom remains in the lowered position until the pot comes to the surface. A hook fixed to the end of the boom by a short chain is attached to the bridle or pot frame so that the pot can safely be brought aboard by topping and swinging the boom.

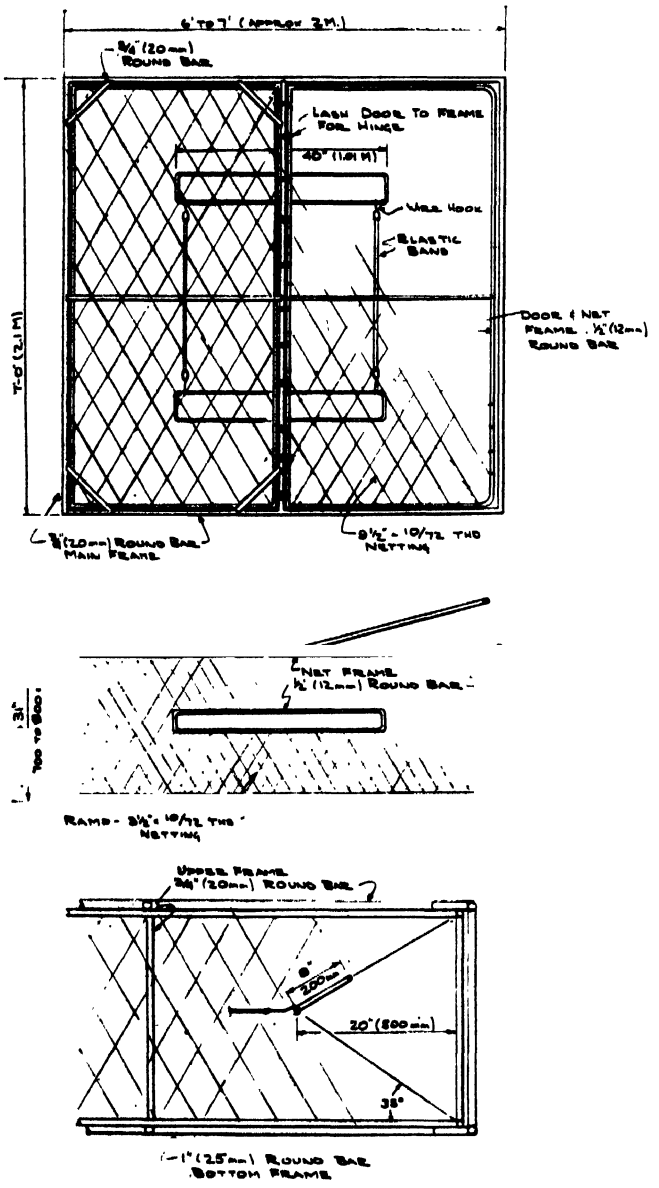

Fig. 14. Typical details of Alaska king crab pot.

Future developments

With the increased emphasis on king crab fishing, further developments in gear and methods can be expected in the following areas:

Buoys—The existing floats ride low in the water and are often difficult to locate in bad weather. A new design incorporating radar reflectors and balloons that can be

Fig. 15. King crab (Paralithodes Camtchatica).

Les Madraques Atlantique et Sicilienne

Résumé
Le mou donné aux filets constitue la principale différence de construction des madragues atlantique et sicilienne. Dans la madrague atlantique, la profondeur des filets est de très peu supérieure à a profondeur de l'eau au site tandis dans la madrague sicilienne les filets ont normalement un tiers de plus que la profondeur du site. Ceci a une répercussion sur la comportement de la madrague sous l'effet des courants. Ainsi, les filets de la madrague sicilienne, sous de forts courants, seront tirés au-dessous de la surface et déplaceront éventuellement les pierres qui les maintiennent en place alors que dans la madrague atlantique qui a beaucoup plus de flotteurs amarrés, le lest sera simplement deplacé et se remettra en position correcte dès que le courant diminuera. L'auteur fait remarquer la différence de construction des deux types et signale les avantages et désavantages de chaque madrague. Le Centre Expérimental de Pêche de Sicile a mis au point un type modifié de madrague à thon qui combine les avantages des deux types. Par sa construction la madrague modifiée ressemble beaucoup à la madrague atlantique mais possède une chambre supplémentaire entre la chambre de mort et le corps de la madrague qui est fermé eet ouverte par une porte du type sicilien.

The Mediterranean and Atlantic tuna traps

Abstract
The main difference in the construction of the Atlantic tuna traps compared with the Sicilian traps lies in the looseness of the netting. The depth of netting in the Atlantic trap is very little more than the depth of water at the site, whereas in the Sicilian trap the netting is usually one-third more in depth than the water depth at the site. This has a repercussion on the behaviour of the trap in respect of currents. The netting of the Sicilian trap will, at excessive currents, drag the floats beneath the surface, and eventually displace its sinkers. The Atlantic trap, which is more heavily floated, will, at excessive currents, lift its sinkers which will reset themselves in the correct position when the current decreases. The author discusses the construction details of both types and points to other advantages and disadvantages of both the Atlantic and Sicilian traps. The Sicilian Experimental Fisheries Centre has evolved a modified tuna trap which combines the advantages of both. Constructionally, it is largely based on the Atlantic type but has an additional chamber between the death chamber and the body of the trap and includes also an additional collapsible trap-door system between such chamber and the body of the trap.

Las almadrabas del atlantico y del mediterraneo

Extracto
La principal diferencia entre las almadrabas del Atlántico y las sicilianas es que estas últimas tienen los paños muy flojos. La profundidad de la red en la almadraba del Atlántico es muy poco mayor que la del agua en el lugar en tanto que las sicilianas son un 30 por ciento más profundas que el agua. Esto repercute en sus movimientos en las corrientes; los paños de las almadrabas sicilianas si la corriente es muy fuerte, arrastran los flotadores debajo de la superficie y llegan a desplazar el lastre. La almadraba del Atlántico que tiene muchos más flotadores, levanta el lastre si la corriente es muy fuerte, pero lo deja caer en el mismo lugar cuando disminuye su intensidad. El autor explica los detalles de la construcción de ambas clases y cita sus ventajas e inconvenientes. El Centro de Pesca Experimental de Sicilia ha preparado una almadraba modificada que combina las ventajas de ambas. Desde el punto de vista de la construcción, se basa principalmente en la del Atlántico, pero entre la camara de la muerte y el cuerpo tiene una camara mas y un doble sistema de trampas plegables.

by
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UNE madrague est conçue surtout pour la pêche des thons rouges, mais elle peut aussi bien pêcher d'autres poissons migrateurs: germon, bonite, espadon. Requins de différentes espèces, marsouins et sérioles sont aussi fréquemment pris dans les madragues, tout comme certains poissons assez rares en Méditerranée tels que les esturgeons. Dans certains endroits, les madragues peuvent capturer des quantités parfois importantes de sardines, anchois, maquereaux, saurels.

Principes generaux

La madrague est un engin de pêche compris dans la grande catégorie des trappes et se base sur deux principes de capture, l'interception des poissons et leur concentration dans une zone restreinte oú la capture est possible.

Une madrague se compose donc d'au moins deux parties:

(1) un barrage plus ou moins perpendiculaire au rivage dit "queue" qui sert à l'interception et au déroutement du poisson.
(2) deux ou plusiers chambres qui forment le corpe proprement dit de la madrague (Isola), où ls

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seen at greater distances would reduce the time spent in locating pots.

Line coiling mechanism—The present rate of hauling (300 fpm) is limited by the ability of a man to hand coil the line on deck. An automatic coiler, which would operate regardless of knots, would speed up the hauling and also free a man to sort crabs.

Rigging to handle pots on deck—The 7 × 7-ft pots weigh 250 lb and require several men to move them around the deck of larger vessels to a stowed position. A rotating crane or highline arrangement would be helpful (Fig. 14).

New types of pots—Further research in pot design is indicated by the various changes which are taking place throughout the fleet. A pot is needed which can be folded or stacked one in another so as to allow more efficient use of deck space.

Mechanised unloading—A mechanical method of unloading to replace the manhandling of every crab would increase efficiency considerably. (Fig. 15.)

Detection equipment—A means of locating crabs prior to setting pots would greatly increase productivity.

poisson se rassemble; c'est dans la dernière chambre que s'effectue la capture.

On conçoit facilement que, théoriquement, la capacité d'interception et aussi de production de la madrague soit en rapport avec la longueur du barrage. Cette longueur est elle-même conditionnée par la profondeur qui, comme on va le voir, ne peut excéder certaines limites et pourtant, dans de nombreux cas, la madrague est complètée d'une queue supplémentaire qui s'étend du corps vers le large (codardo).

Les figures 1 et 2 donnent les plans schématiques des madragues sicilienne et atlantique.

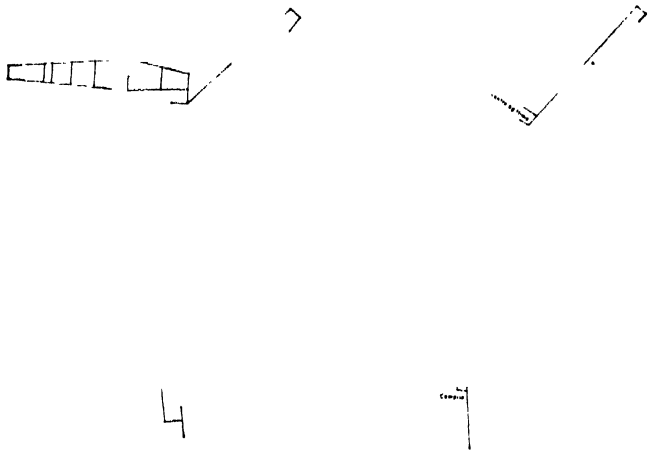


Fig. 1. Plan d'ensemble de la madrague sicilienne.
Fig. 2. Plan d'ensemble de la madrague atlantique.

La madrague atlantique intercepte les poissons non seulement au moyen de la queue et éventuellement du codardo, mais aussi par une méthode de barrages successifs se terminant en crochets, orientées perpendiculairement à la queue, du côté où l'on attend le poisson.

Bien que plusiers madragues soient exploitées le long de la côté Atlantique d'Espagne et du Maroc, cet engin est surtout employé en Méditerranée où les marées sont faibles. Dans les régiones à marées fortes, le problème de la flottabilité présente des difficultés presque insurmontables.

Bien que la question des migrations des thons soit toujours ouverte et que les théories les plus disparates et contradictoires aient été énoncées, depuis Aristote à nos jours, il faut convenir que les thons, en Méditerranée semblent avoir tendance à se déplacer dans la direction générale du courant. Les madragues en conséquence ont leur bouche orientée face au courant dominant (à l'époque de la pêche). On sait que le courant dominant en Méditerranée se dirige vers l'est le long des côtes d'Afrique et en sens contraire le long des côtes Européennes, ce qui fait que les madragues de l'Afrique du Nord ont la bouche vers l'ouest et celles de la côte nord de la Sicile, vers l'est.

La limite technique de la madrague réside dans la possibilité d'en assurer le flottement, l'aplomb, le calage et le maintien de l'installation en état de fonctionnement dans des conditions variables, souvent par mers et courants très forts.

Le corps d'une madrague se situe par 50 ou 60 mètres de fond et les filets vont de la surface jusqu'au fond. En plus du poids de l'engin même, l'effet des courants sur des nappes de filets d'une telle hauteur et d'une longueur pouvant atteindre plusieurs milles, mettent en jeu des forces considérables et posent des problèmes de flottaison.

La chambre de capture ou chambre de la mort qui est la seule partie mobile de la madrague, doit pouvoir être relevée du fond et de la rapidité de l'opération dépend le succès de la pêche. Son poids propre et les forces exercées sur elle par les courants, ne peuvent dépasser certaines valeurs qui limitent les dimensions de chaque installation, suivant les conditions bathymétriques de la zone.

En ce qui concerne le choix des zones, il faut préciser que s'offrent deux possibilités:

(a) placer la madrague sur la route de migration principale des thons.
(b) intercepter les thons à l'intérieur des golfes lorsqu'ils approchent de la côte pour frayer.[1]

Ceci ne veut pas dire que le thon génétique ou de course, ne puisse se pêcher qu'avec des madragues de golfe, car les madragues placées sur le prolongement des caps en interceptent de grandes quantités au cours de leurs déplacements vers les frayères.

Le thon dit de retour au contraire, ayant déjà frayé, ne s'engage plus dans les golfes et ne peut se pêcher qu'avec des madragues de pointe (de caps) lors de leur migration trophique, des frayères aux lieux d'hivernage. Cette deuxième migration s'effectue d'est en ouest et la route empruntée, par suite de la propension du thon à se déplacer avec le courant, longe les côtes sud de l'Europe et particulièrement la côte sud-ouest de la Sicile.

Les madragues de course siciliennes sont traditionnellement des madragues de golfe et leur technique a évolué selon les conditions hydrologiques des zones exploitées. En Atlantique et en Espagne où les courants sont plus forts on a développé des techniques particulières, ce qui fait que la madrague de type atlantique diffère sensiblement du type sicilien traditionnel.

Le developpement de la motorisation des bateaux de pêche ou de plaisance, la pêche au feu, les residus des usines, etc., dérangent les thons lors de leur passage à proximité de la côtes, et ont provoqué leur raréfaction à l'interieur ces golfes et a eu pour conséquence la suppression de la plupart des madragues siciliennes. D'où la nécessité de réexaminer la théorie de la madrague sicilienne afin de choisir de nouveaux emplacements sur le prolongement des caps où se tient le thon à présent.

Depuis quelques années déjà le Centre expérimental pour la Pêche de la Région Sicilienne porte toute son

[1] Le thon effectue au printemps une migration génétique de ses lieux d'hivernage (quels qu'ils soient) vers les frayères; celles-ci ne sont pas toutes connues, mais on peut citer parmi elles, la basse Tyrrhénienne, les deux Syrtes, l'ouest de la Sardaigne, etc.

attention sur ce point et propose maintenant un troisième type de madrague qui réunit en théorie les avantages des madragues atlantiques et siciliennes, mais dont les résultats pratiques sont encore à vérifier pendant plusieurs saisons de pêche.

Quel que soit le type de la madrague, le point essential est que l'ensemble doit maintenir sa forme et sa place durant la saison de pêche puisqu'il s'agit d'une installation fixe.

Dans la madrague sicilienne le bas des filets est fortement lesté au moyen de grosses pierres de forme irrégulière qui s'enfoncent dans la vase du fond et en assurent l'inamovibilité. La ralingue supérieure formée d'un câble en acier de 24 mm ϕ est tenue en place par un système de câbles aboutissant à des ancres de plusieurs centaines de kilos chacune. Ces amarres sont couplées, à des intervalles variables, sur la ralingue de surface à un intervalle moyen de 20 brasses. Les câbles d'amarre sont longs d'au moins trois fois la profondeur et la chute des filets est au moins ½ plus longue que la profondeur ce qui laisse 33 pour cent de mou. Le flottement est assuré par des bouées métalliques ou en plastique ou par des paquets de liège ou de polystirol, placés à même le câble de la ralingue supérieure. Il doit être équilibré de telle façon que, sous l'action d'un courant d'environ 1 noeud/h tout l'ensemble de l'installation commence à sombrer.

Les figures 3 et 4 montrent schématiquement, en-

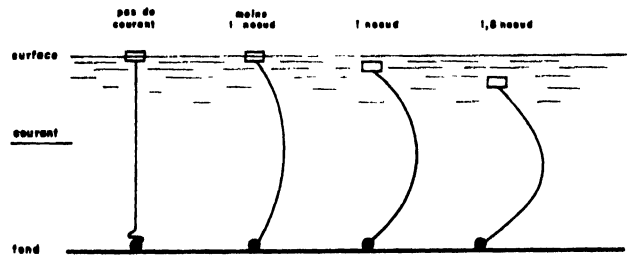


Fig. 3. Madrague sicilienne.

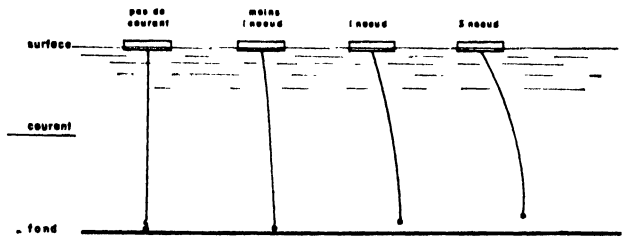


Fig. 4. Madrague atlantique.

coupe verticale, la position que prend le filet des madragues sicilienne et atlantique respectivement, sous l'action de courants de différentes forces.

Madrague sicilienne

Le bas du filet est fortement lesté et inamovible sur le fond. A faible courant, le mou du filet se rassemble vers le bas, les câbles d'amarre décrivent une courbe en S, leur partie inférieure gisant sur le fond pour environ ½ de la longueur totale. Avec un courant allant jusqu'à 1 noeud/h environ, les câbles d'amarre ne bougent pas et la ralingue de surface est toujours sur le même aplomb que la ralingue inférieure qui est inamovible, mais le mou du filet est progressivement engagé. Si la force du courant dépasse 1 noeud/h, les câbles d'amarre du côté de la provenance du courant se tendent tandis que ceux du côté opposé se relâchent; la ralingue supérieure se déplace en surface et ensuite commence à s'immerger; la courbe formée par le mou du filet a tendance à s'aplatir. Avec un courant de 1·8 noeuds/h, la ralingue de surface est entrainée à environ 10-12 mètres sous l'eau et dérive d'autant que le permet le raidissement du câble d'amarre. Avec des courants encore plus forts, les ancres des câbles d'amarre chassent ou bien les câbles cassent. Il se peut encore que le filet se déchire, ou enfin que la ralingue de fond et son lest se déplacent. Dans chacun de ces derniers cas le dégat est irreparable.

La limite de sécurité de la madrague sicilienne se situe donc à une force de courant d'environ 1·8 noeud/h. En-deçà de cette limite de sécurité, tout l'ensemble reprend progressivement sa position de départ, dès que le courant diminue d'intensité.

Madrague atlantique

Dans la madrague atlantique, c'est la ralingue de surface qui est inamovible et ne peut sombrer. Ceci s'obtient en renforçant le nombre des câbles d'amarre et le poids des ancres et en multipliant le nombre et les dimensions des flotteurs. Par contre, la chute du filet est sensiblement égale à la profondeur (mou, environ trois pour cent) et le lest composé de chaînes est très léger afin de pouvoir se déplacer faiblement sur le fond sans s'accrocher et s'enraciner. Sous l'action des courants, le filet exécute un mouvement pendulaire et reprend automatiquement son aplomb quand le courant cesse. La sécurité de l'emplacement de la madrague atlantique n'est donc jamais compromise à cause des courants, quelle que soit leur force. Le pire qui puisse arriver est de ne pas pêcher normalement pendant un certain nombre de jours et de perdre par le fond, les poissons déjà enfermés dans la chambre puisqu'après les forts courants l'installation se remet en place d'elle-même. En outre, la madrague atlantique étant construite avec un matériel de meilleure qualité que la madrague sicilienne, les filets peuvent se faire plus elairs etoffrent ainsi une moindre résistance aux courants.

Le filet de la madrague sicilienne, enraciné au fond ne peut se récupérer en fin de saison. Il doit donc être fait de matière bon marché (Ampelodesmus ou, au plus, coco) qui n'a qu'une faible résistance à la rupture. C'est pour cette raison qu'il est formé de mailles plus petites et monté sur la ralingue à intervalles plus rapprochés qu'il ne serait nécessaire pour empêcher les poissons de s'échapper.

Dans la madrague atlantique, la légèreté du lest permet la récupération des filets qui, en conséquence, se font en sisal ou en manille voire même en nylon. Ce matériel plus fort permet d'avoir des mailles plus grandes et plus ouvertes avec une diminution correspondante de poids et de résistance aux courants; de plus, la suppression presque totale du mou amène une diminution de 30 pour cent de la superficie de filet que le courant doit traverser.

Plus importante encore est peut-être la construction beaucoup plus simple du corps de la madrague qui se réduit à une seule chambre de rassemblement du poisson et à une chambre de mort. C'est de cette deuxième caractéristique principale de la madrague atlantique que découle la suppression du mou des filets; seuls les filets ayant une chute légèrement supérieure à la profondeur permettent de réaliser une bouche en souricière qui, en même temps qu'elle empêche les poissons déjà pris de s'échapper, laisse l'entrée libre pour ceux venant de l'extérieur (voir Fig. 5).

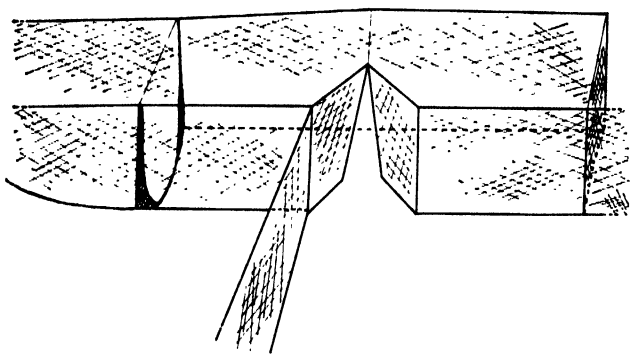


Fig. 5. Madrague atlantique. Detail de la bouche.

Dans la madrague sicilienne, le mou empêche de réaliser une telle bouche en souricière, puisque le filet se disposerait comme les pans d'un rideau ne laissant qu'une petite ouverture d'entrée qui se boucherait complètement avec le moindre courant. Empêcher le poisson déjà engagé dans la madrague d'en sortir tout en laissant la bouche ouverte pour faciliter l'entrée des poissons encore à l'extérieur, telle est l'explication du grand nombre de chambres de la madrague sicilienne. Les différentes chambres sont munies de portes formées de nappes de filet dont le bas est enraciné au fond et dont les deux côtés sont cousus aux parois de la madrague tout en formant, de chaque côté, un gousset qui donne l'amplitude nécessaire pour permettre à la nappe de filet constituant la porte, de descendre jusqu'au fond. L'effet des courants sur les portes provoque une déformation et une

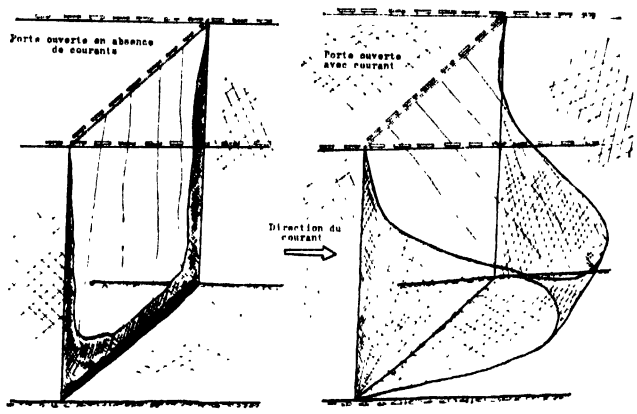
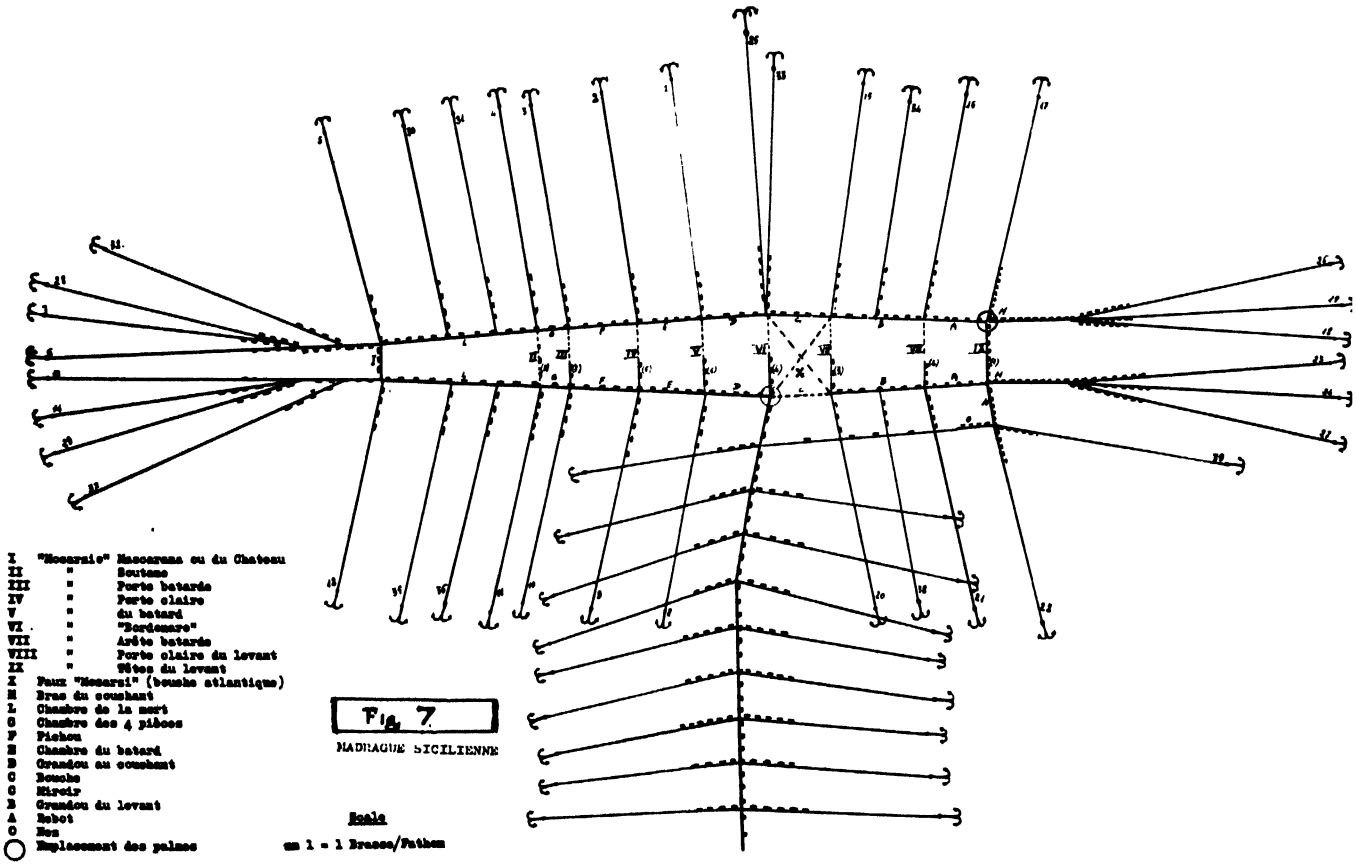


Fig. 6. Madrague sicilienne.



dérive beaucoup plus grande que celles subies par les parois de la madrague et les filets de la queue puisqu'il faut ajouter au mou normal de 33 pour cent, l'amplitude des deux goussets. (Voir Fig. 6.)

Dans les deux types de madragues la construction en mer qui prend plusieurs jours, commence par l'installation et l'amarrage du câble de surface. La madrague sicilienne exige que les alignements, croisements, insertions des portes et autres parties de l'ensemble, soient très exacts et les câbles de surface mesurés avec précision. La pose des ancres et câbles doit se faire selon une procédure compliquée, deux ancres à la fois et au même moment, des deux côtés du câble de surface. Le câble de surface, utilisé pendant l'installation des amarres n'est que provisoire et est remplacé par le vrai auquel est attachée la ralingue supérieure des filets, au moment où ceux-ci se mouillent.

Dans la madrague atlantique cette précision du dessin n'est pas indispensable, les câbles de amarre se font en acier d'un bout à l'autre, et le câble de surface définitif est mis en place en même temps. On peut indifféremment mouiller les amarres d'abord d'un côté et puis de l'autre ou compléter tout un côté et terminer par l'autre. La figure 7 donne des détails de l'amarrague du corps et de la partie supérieure de la queue d'une madrague sicilienne.

Le calage des filets

Une fois le lest posé sur le fond, son emplacement est fixé pour toute la saison, et il est essential que la ralingue du fond soit parfaitement à plomb avec la ralingue supérieure. Le calage des filets est donc l'operation la plus délicate de la construction de la madrague sicilienne. Les deux moitiés des portes cousues au filet, chacune par son gousset, sont réunies entre elles au moment du calage et se posent sur le fond au même instant, avec leur lest. Les bateaux porteurs des deux moitiés de la madrague sont halés sur un alignement rigoureux le long du faux câble de surface, qui est remplacé par le vrai câble de surface au fur et à mesure que l'opération progresse et que les filets sont mouillés.

Ces opérations qui prennent de 6 à 8 heures exigent des conditions hydrologiques et météorologiques très favorables puisque le calage, une fois commencé, ne peut être interrompu.

La madrague atlantique qui elle, n'a pas de portes, se cale beaucoup plus facilement. On commence par l'un des côtés de la souricière et on continue le calage en contournant le périmètre de la madrague (Fig. 8). A

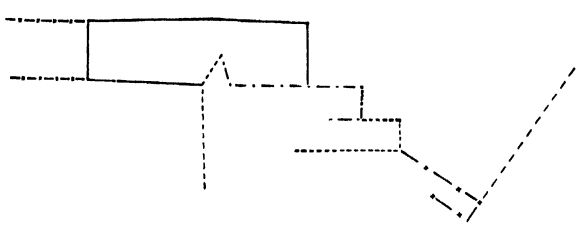


Fig. 8 Schema indicatif des differentes phases de mouillage des filets

tout moment on peut interrompre l'opération; il suffit de découdre le filet non encore calé, au point où on est parvenu. Pour reprendre le calage, il suffit de haler la ralingue du fond du filet déjà en mer et recoudre le filet pour continuer. Le câble de surface ne pose aucun problème car il est mis en place indépendamment des filets. Pour les deux types de madrague la queue et les barrages accessoires externes se calent successivement. Cependant, si relier le filet de queue au corps déjà en mer ne présente aucune difficulté pour la madrague atlantique, l'opération pose un sérieux problème pour la madrague sicilienne dont la ralingue de fond ne peut plus se haler une fois en mer.

Dans les deux types de madrague, le calage de la chambre de la mort, complète les opérations de construction de la trappe. La chambre de la mort prolonge la madrague vers l'ouest et se situe sur le même alignement que le corps de celle-ci dont elle est séparée par la porte dite "de chanvre". Schématiquement, elle prend en mer la forme d'un demi tronc de cône: la semi-circonférence majeure rattachée au corps de la madrague, les deux côtés longs, montés sur le prolongement des câbles de surface des filets, la semi-circonférence mineure aboutissant sur le bord d'un bateau de longueur proportionnée, placé en travers del'axe de la madrague.

La semi-circonférence majeure est cousue à la partie inférieure de la porte de chanvre et, en même temps à une pièce de conjonction avec les filets du corps. Cette pièce, dans la madrague atlantique est constituée simplement par une paire de goussets, tandis que dans la madrague sicilienne elle comporte plusieurs éléments (sous-fonds, pièces de l'arrière, etc.) très étudiés et astucieusement conçus, et qui rendent infiniment plus efficaces les opérations de halage.

La composition de la chambre de mort peut varier à l'infini; le principe essentiel est qu'elle doit être assez résistante pour supporter le halage qui se fait parfois plusieurs fois par jours, et sa partie terminale (vers la semi-circonférence mineure) doit pouvoir contenir plusieurs tonnes de gros poissons tirés presque à sec sans être trop lourde afin que le halage ne présente pas de difficultés insurmontables.

La figure 9 donne le détail de la composition d'une chambre de la mort de madrague sicilienne qui pourrait tout aussi bien s'employer dans une madrague atlantique.

Les operations de pêche

Dans la madrague atlantique le rassemblement du poisson ne demande aucune intervention de la part de l'homme. Les thons ou autres poissons recontrant le barrage de la queue, la longent. S'ils font route vers le large, ils recontrent la bouche en souricière, s'engagent dans la madrague et ne peuvent en ressortir; s'ils font route vers la côte, ils rencontrent aussitôt un crochet qui les fait rebrousser chemin et les achemine vers la bouche; s'ils s'éloignent de la queue en direction du large, ils recontrent les barrages extérieurs de la légitima et contralegitima, avec leurs crochets qui, eux aussi, les acheminent vers la bouche ou de nouveau vers la queue.

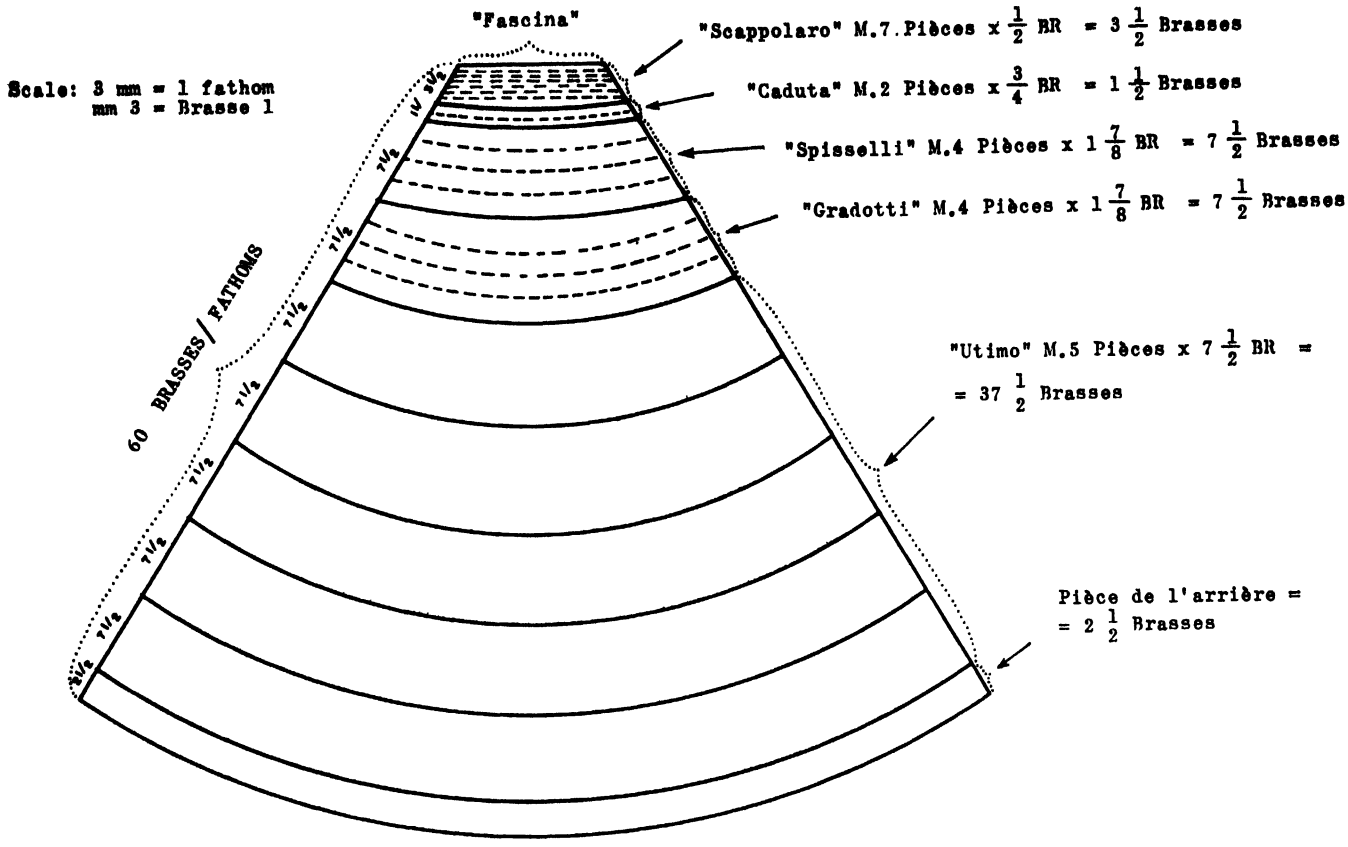


Fig. 9. Composition de la chambre de la mort de madrague sicilienne.

Il est très improbable que des poissons tombés dans la zone de pêche d'une madrague puissent éviter de finir tôt ou tard dans la chambre.

Dans la madrague sicilienne les choses se passent de la même façon jusqu'au moment où le poisson entre par la bouche; celle-ci n'étant pas en souricière, permet la sortie aussi bien que l'entrée et il faut prendre des mesures pour empêcher que les poissons ne s'évadent. Plusieurs bateaux guetteurs sont placés sur le travers de la madrague au-dessus des portes; les guetteurs montent la garde soit à la vue, soit avec des lignes de touche en nylon se terminant par un lest en plomb; les groupes de thons en passant frôlent ces lignes qui transmettent une vibration avertissant le guetteur. Une longue expérience permet d'interpréter ces faibles indices et de se rendre compte du nombre et de la taille des poissons nageant en profondeur. Aussitôt que les poissons se sont engagés dans une chambre, on relève la porte et on repète l'opération pour la chambre suivante jusqu'à regrouper tous les poissons dans la dernieère chambre qui précède celle de la mort. A ce point-ci la situation se présente de la même façon dans les madragues des deux types c'est-à-dire, que les poissons sont regroupés dans une enceinte dont ils ne peuvent sortir et qui est séparée de la chambre de la mort par une seule porte, la porte de chanvre. A partir de ce moment, le système sicilien est incomparablement plus avantageux. Dans la madrague sicilienne les poissons qui se trouvent assez à l'étroit dans la chambre du pichou se ruent vers la chambre de la mort, dont ils ne peuvent apercevoir l'extrémité opposée et qui leur apparait alors comme mer libre. Dans la madrague atlantique où l'unique chambre de rassemblement est immense, ils n'ont pas la même impression et le passage à la chambre de la mort se fait avec beaucoup plus de difficultés, le plus souvent par petits groupes séparés ce qui fait qu'un groupe entre, un autre sort et quelquefois des heures passent avant de pouvoir relever la porte de chanvre et commencer le halage de la chambre de la mort qui se termine par la capture ou mattanza.

Il est à remarquer que les capitaines espagnols ne connaissent pas l'usage des lignes de touche et ne se servent que de leurs yeux pour reconnaître la présence des thons dans la chambre de la mort. Or si le poisson nage en profondeur, hors de la portée de la vue, il se peut qu'il entre dans la chambre de la mort et en ressorte sans que personne ne s'en aperçoive; le filet qui forme le fond de la chambre s'élève graduellement en transversale de l'est vers l'ouest; quand le poisson recontre ce fond, il en est facilement effrayé et rebrousse chemin. Le maître de pêche sicilien au contraire, place son bateau avec sept autres guetteurs à moitié de la chambre de la mort et un deuxième bateau en parallèle, un peu plus vers l'ouest; le guet se fait soit visuellement, soit avec les lignes de touche. Le poisson qui entre est détecté quand il n'est qu'à mi-chemin vers l'ouest et la porte de chanvre est levée avant qu'il ne rebrousse chemin, la porte de

Eel Traps Made of Plastic

Abstract
Much of the eel catch in European countries, from rivers and estuaries, is made with traps of willow, rattan or other wooden lattice work lasting in most cases no more than one year.

The Institute has, since 1961, carried out experiments with traps made of plastic material. The trials showed that polyethylene became too flexible during the warm season so that eels escaped by squeezing between the laths; its low density of 0·94 on the other hand caused no problems. Polyamide was more stable but much too expensive for commercial application. The best material proved to be polyvinyl chloride, but as PVC alone was found to be rather brittle at low temperatures a special mixture, found to be available in the chemical industry, was used.

The first plastic traps used in 1961 were of the same design as the traditional types and on average caught 20 per cent less. The experiments did, however, show that the material itself did not affect the catch and that the decrease in catch was due to faulty construction.

In 1962 further experiments were carried out with more tightly woven plastic traps, which resulted in catches which were on a par with those of the traditional types. The production cost of these plastic traps is three times higher than for willow traps, but as their useful life is many times greater, they should be more economical.

by
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A solution to the time-consuming task of making traps could be ound by casting them from suitable moulds such as were produced fn Germany.

Casiers a anguilles fabriques en matiere plastique

Résumé

Une grande partie des anguilles capturées dans les pays Européens, principalement dans les rivières et les estuaires, est obtenue à l'aide de casiers en saule, rotin ou lattis, bien que toutes ces fabrications durent rarement plus d'un an.

continued from page 276

chanvre pouvant être relevée en 3, 4 minutes. Dans ce but la connection entre les filets du corps et la chambre de la mort est plus compliquée que celle de la madrague atlantique. Pour haler la porte de chanvre il faut lever toute la porte avec ses connections sur le corps et à l'avant, c'est-à-dire la semi-circonférence majeure de la chambre de la mort. Les pièces de connection de la madrague sicilienne sont ainsi faites qu'aucune résistance ne vient du filet du corps car la pièce de l'arrière et les sous-fonds qui, normalement gisent au fond, se déploient en éventail et donnent tout le mou nécessaire pour lever. Dans la madrague atlantique il faut vaincre la résistance des filets du corps qui sont en partie soulevés avec leur lest, ce qui présente le double inconvénient d'offrir aux poissons qui éventuellement sont restés dans la chambre, une voie de liberté vers le bas et de rendre le lever de la porte beaucoup plus difficile. Une fois la porte de chanvre levée, les opérations se poursuivent de manière à peu près semblable dans les deux types d'engins: au fur et à mesure que le bateau d'où l'on fait la levée, avance vers l'extrémité ouest, la chambre de la mort se rétrécit et se soulève jusqu'à se réduire à un carré d'une quinzaine de mètres de côté et de deux ou trois mètres de profondeur où la tuerie a lieu.

Type de madrague modifiée

La présente communication avait pour but, sans entrer dans tous les détails, de faire ressortir la grande supériorité technique de la madrague atlantique par rapport à la sicilienne quant à sa conception générale, et de montrer quels sont les détails ou le systeme sicilien est plus avantageux. Nous pouvons maintenant présenter le type modifié qui est proposé par le Centre Expérimental pour la Pêche de la Région Sicilienne et dont le plan schématique est représenté. (Fig. 10.) Ce nouveau type adopte la bouche en souricière, le système de lestage, de

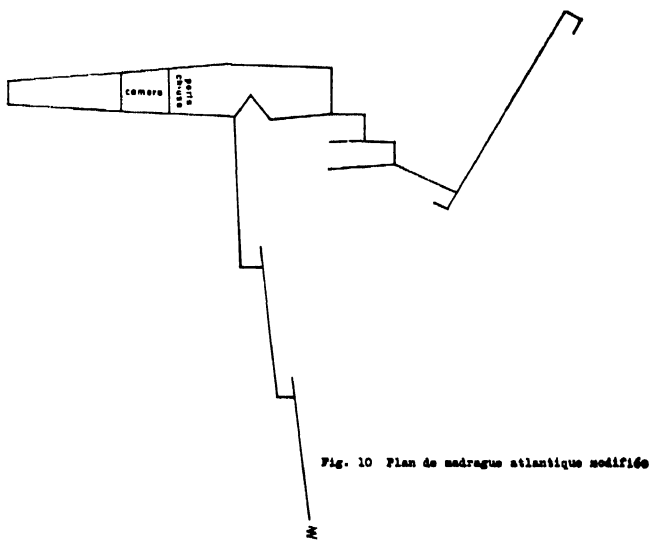


Fig. 10 Plan de madrague atlantique modifiée

flottaison, d'amarrage, la longueur et la qualité des filets de la madrague atlantique mais interpose une chambre supplémentaire entre celle de la mort et le reste du corps; ceci a pour but de rassembler le poisson dans un espace plus restreint pour faciliter son passage dans la chambre de la mort. La seconde modification structurale porte sur l'adoption du système sicilien pour la connexion entre corps et chambre de la mort. Le principe des lignes de touche et des bateaux de guet doit être retenu puisque les conditions de pêche en Méditerranée sont différentes de celles de l'Atlantique et requièrent d'autres techniques telles que celles employées par les pêcheurs siciliens qui, à cause de la plus petite quantité de poisson qu'intercepte une madrague de golfe, sont obligés de recourir à toutes les ruses et à perfectionner une "finesse" du métier qui se transmet d'une génération à l'autre.

A l'Institut, depuis 1961, des expériences ont été faites avec des casiers fabriqués en matière plastique. Ces expériences ont prouvé que le polyéthylène devenait trop flexible pendant la saison chaude permettant ainsi aux anguilles de s'évader en se glissant entre les lattes. Par contre, sa densité de 0·94 ne posait aucun problème. Le polyamide plus stable, s'avérait trop coûteux pour une application commerciale. C'est en définitive le polyvinyl chloride qui a paru être la meilleure matière bien que celle-ci soit encore trop fragile à basse température. Un mélange spécial a été trouvé et expérimenté dans l'industrie et s'est révélé de meilleure qualité:

Les premiers casiers en plastique, fabriqués en 1961, étaient du même modèle que ceux de type traditionnel mais capturaient environ 20 pour cent de moins que ces derniers. Les expériences cependant ont montré que la matière, elle-même n'avait aucun effet sur la capture et que cette diminution était due à une fabrication défectueuse.

De nouvelles expériences conduites en 1962, avec des casiers en matière plastique, plus serrés que les précédents, ont permis d' obtenir des captures égales à celles effectuées avec des casiers traditionnels. Ces casiers sont à peu près trois fois plus chers que les paniers en saule mais, étant donné qu'ils durent beaucoup de fois plus longtemps, ils sont finalement plus économiques. Il est proposé de réduire le temps de fabrication de ces casiers, actuellement assez long, par l'emploi de moules.

Trampas de material plastico para la pesca de la anguila

Extracto

La mayor parte de las anguilas pescados en los ríos y estuarios Europeos, se capturan con trampas hechas de ramas de sauce, bejucos y otras maderas, la mayor parte de las cuales dura menos de un año.

El Instituto realiza desde 1961 experimentos con trampas hechas de material plástico. En los ensayos se observó que el polietileno adquiere demasiada flexibilidad durante el tiempo cálido y que las anguilas escapaban pasando por el entramado; por otro lado, su baja densidad de 0·94 no planteaba problemas. El poliamido era más estable pero mucho más caro y por ello menos conveniente para su empleo en la práctica. El mejor material resultó ser el cloruro de polivinilo, pero como por sí solo resultaba bastante quebradizo a temperaturas bajas se empleó una mezcla especial que la suministra normalmento la industria química.

Las primeras trampas de material plástico empleadas en 1961 eran de la misma forma que las tradicionales y por término medio pescaban un 20 por ciento menos. Sin embargo, los experimentos demostraron que el material en sí mismo no influía en la captura y que su disminución se debía a una construcciόm defectuosa.

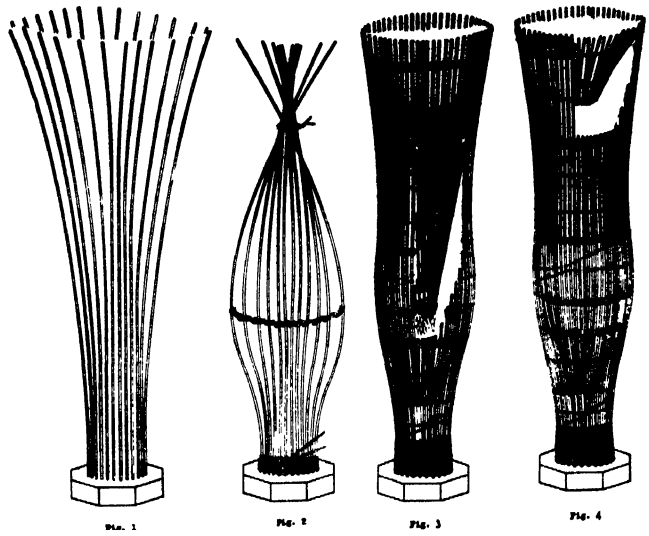
En 1962 se realizaron otros experimentos con trampas de material plástico de entramado más apretado con las que se lograron capturas iguales a las obtenidas con las trampas adicionales. El costo de producción de estas trampas de material plástico es tres veces mayor que el de las trampas de sauce, pero duran muchos veces más, por lo que deberían de resultar más económicas.

La larga tarea de fabricar las trampas puede reducirse al mínimo haciéndolas en los moldes convenientes, como se practica ya en Alemania.

IN many European countries eel traps of basketwork (willow, rattan or wood) are still used in rivers and estuaries. After one year they are often in need of repair and after two years they have to be replaced. Furthermore, they must be dried from time to time, otherwise they smell foul and repulse the eels.

These drawbacks could be avoided by using non-rotting synthetics. Since 1961, the Institut für Netz- und Materialforschung, Hamburg, has carried out investigations with traps made of polyamide, polyethylene and polyvinyl chloride (PVC). These tests were made in areas affected by tides. In the first year the trials were not successful as some materials proved unsuitable, or the traps were not properly built.

Polyethylene (density 0·94) became too flexible during the warm season. A large number of the eels already



Figs. 1-4. Method of building a plastic eel trap.

caught escaped through the bars. Also pure polyethylene tends to float.

Polyamide-sticks (density 1·14) were more stable; but too expensive.

Polyvinyl chloride (PVC) (density 1·38) proved most suitable. In low temperature pure PVC is admittedly short and brittle. But a special mixture, resistant to cold and breaking, is now available.

In 1961 the plastic traps were still copies of the willow

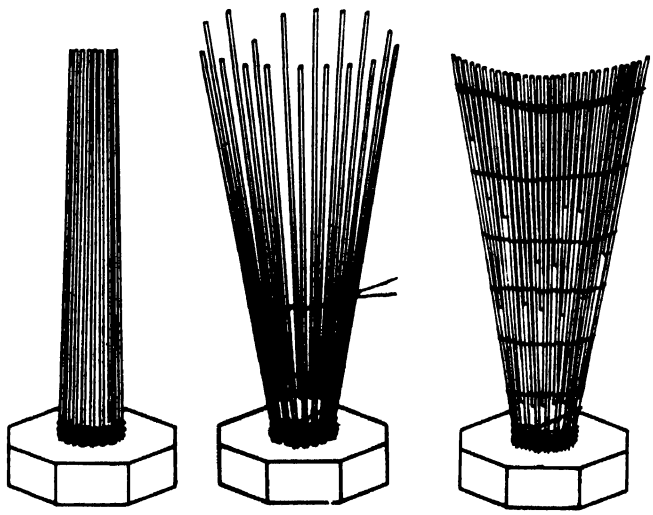


Fig. 5. Building of the long funnel.

traps and therefore some small eels could escape. Checks made in the estuary of the river Ems in Northern Germany showed that the catch of these first traps was 20 per cent less than that of the traditional ones. But it was evident that plastics were, in principle, suitable.

For the season of 1962 the PVC traps were plaited more closely, so that the intervals between the rings in the

continued at foot of page 279

Types of Philippine Fish Corrals (Traps)

Abstract
One of the most important fishing gears operated in sheltered waters of the Philippines, by both sustenance and commercial fishermen, is the fish corral. It is set across the migration routes of fishes, which affords them easy entrance to one or more compounds where they are impounded. The walls of the fish corral are made of bamboo splits which are laced together and held in position by means of stakes or posts. Because the materials used in the construction are abundantly found in the Philippines, the use of this gear is widely spread. They also vary in forms and sizes, depending upon the conditions obtained in the fishing ground and the capital of the operator. This paper describes, with illustrations, the different types of fish corrals in the Philippines.

Types de barrages dans les Philippines

Résumé
Un des plus importants engins de pêche utilisés dans les eaux abritées des Philippines, même à l'échelle commerciale, est le barrage. Il est construit sur la route de migration des poissons de telle façon que ceux-ci puissent y entrer facilement, mais ne puissent en ressortir. Le barrage est construit de bambous fendus, nattés et tenus en position verticale à l'aide de poteaux. Les matériaux nécessaires à la construction de ces barrages abondent aux Philippines c'est pourquoi ce type d'engin est utilise sur une grande échelle dans cétte region. Les barrages sont de formes et de dimensions différentes suivant le lieu de pêche et les moyens financiers de l'opérateur. L'étude décrit avec illustrations, les différents types de barrages de poissons utilisés aux Philippines.

Clases de corrales de pesca de las Filipinas

Extracto
El corral es uno de los más importantes artes de pesca empleados en aguas protegidas de las Filipinas por pescadores de subsistencia e industriales. Colocado a través de las rutas de emigración, tiene entradas fáciles a uno o más corrales de los que no pueden salir los peces. Las paredes del corral son de bambú hendido, trenzado y mantenido en posición por medio de postes. Como el bambú abunda mucho en las Filipinas el empleo de estos corrales está muy extendido. Las formas y dimensiones dependen de las condiciones reinantes en los caladeros y del capital del pescador. Describe con ilustraciones esta ponencia las diferentes clases de corrales de pesca empleados en las Filipinas.

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THERE is hardly any sheltered water in the Philippines where fish corrals are not used for either subsistence or commercial fishing. The fact that the materials for

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basketwork did not exceed five cm (as against 8-10 cm in the traditional traps). Trials were made in the mouths of the Ems and Weser. Checks proved that in the Ems catches were as high as those in willow traps. In the Weser they were even five per cent better.

No colour effect was noticed, but whereas in the estuaries the water is always muddy and turbid, in clear water the visibility may be of some importance.

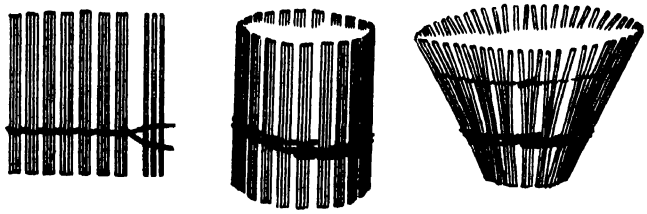

Fig. 6. Building of the short funnel.

These results showed that plastic eel traps are at least as efficient as traditional ones. They need less care in handling and time, and do not rot. Their cost is about three times that of willow traps. But they will probably have a useful life of much more than five years and, therefore, will be more economical.

Last year plastic traps made of mould-cast lattice work were produced by a German plastics manufacturer (Fig. 7). In some respects, this would be a further improvement because every year fewer people are able or willing to make traps by hand. But there is one difficulty: the size of the eels and the size and kind of the bait change with place and season. Because of this the fishermen generally use various types of traps, which differ from 2-8 mm in the space between the sticks. With hand-made traps, it is easy to meet these requirements but manufacture may be uneconomical as the construction of moulds for casting plastics is very expensive.

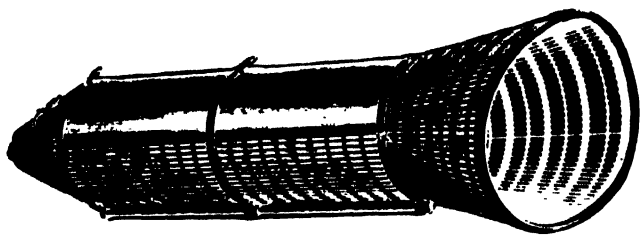

Fig. 7. Eel-trap of cast plastic.

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their construction may be found almost everywhere at any time of the year at low cost, explains the widespread use of this fishing gear.

Fish corrals catch fish by providing a barrier across known or suspected paths of migration of fish and guiding the fish to a one-way enclosure or series of enclosures; hence, the term "guiding barriers".

These fish corrals take various forms, from the small movable weir installed in shallow water to the highly, elaborate affairs operated in deeper waters. The variations in size and form are the result of continuous adaptation by Filipino fish corral operators to varying fishing conditions and the amount of capital available. The various types are classified as *aguila* or *pahubas, inangcla, paugmad, bungsod, zamboanga*, and *hasang*.

Aguila or pahubas

This type of fish corral is constructed on tidal flats partly or entirely exposed at low tide. It usually consists of one or more enclosures with a small collecting crib, a gate, two wings and generally with a leader. The bamboo screens are finer and woven closer together than those used in deeper waters. It is set during the early part of the season and transferred from one place to another for better catches. The gear is usually removed once a month, especially when set in sheltered waters. It catches littoral fishes including crabs, shrimps, squids and mullets.

Based on the shape of the enclosures, aguila fish corrals may be divided into *baklad ordinario and tulis*.

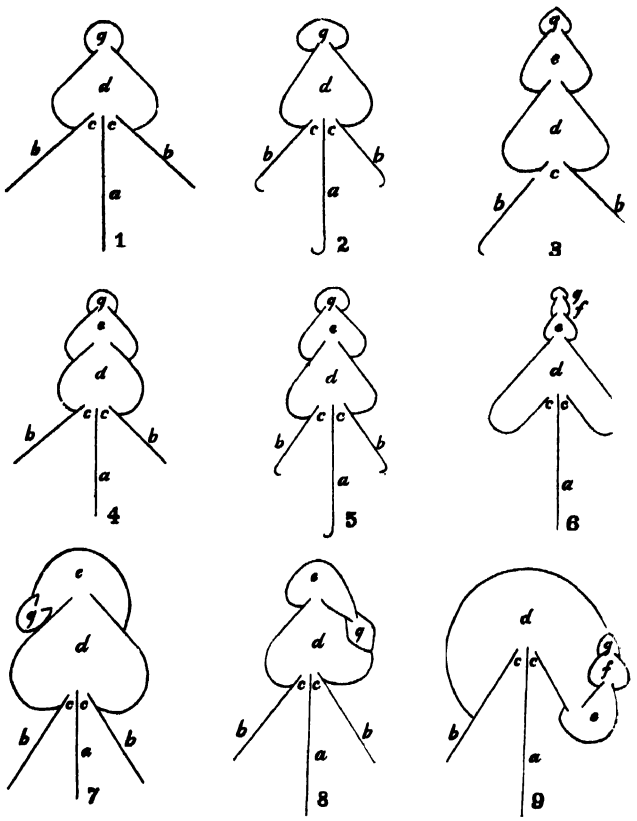
Baklad Ordinario

These are shallow water fish corrals (Figs. 1 to 12) with two or more heart-shaped enclosures, one or two or no wings, with or without a leader. The leader (when present) and wings may be straight or curved at their distal ends. In Busuanga, Palawan Province, the wings are sometimes made of piles of stones. The collecting crib may be terminal in position (located at the end of the heart-shaped enclosure or series of enclosures) or lateral (on left or right arm of the heart-shaped enclosure). The positions of the lateral type of collecting cribs are extremely varied but all are laid out in such a way as to prevent escape of the fish once it enters the first enclosure.

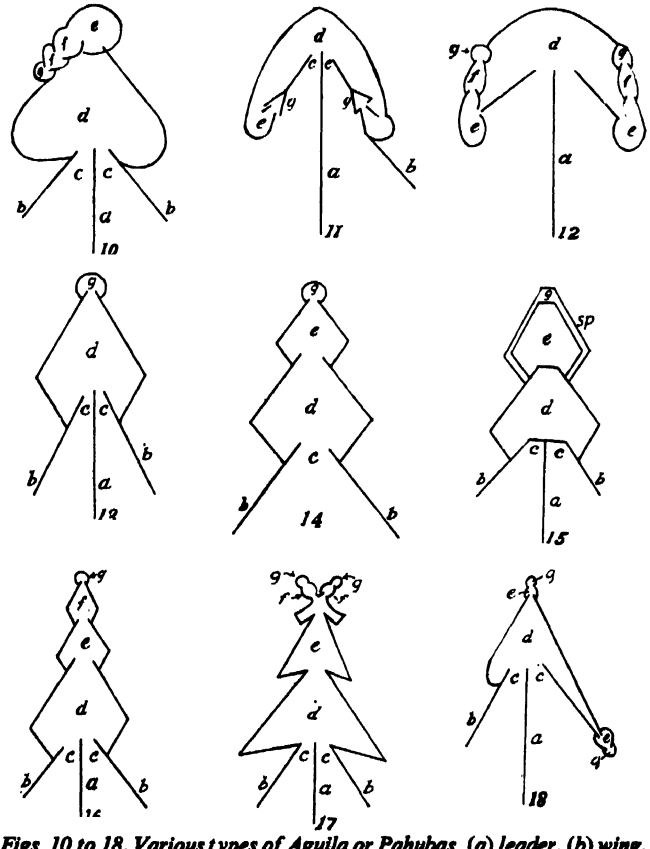
Tulis

Figs. 13 to 18 show the various forms of tulis fish corrals. The term "tulis", which means pointed, is derived from the arrowhead appearance of the fish corral. At least three forms of tulis are recognised; namely *pangalato, baenakan*, and *tulis proper*. Fig. 13 represents the pangalato in Ragay Gulf, the simplest form of tulis. Fig. 15 is a baenakan commonly used near the mouth of rivers in Capiz Province to catch mullets and bangos. The bamboo platform on the sides of the second compartment is where the fish lands when it attempts to jump over the enclosure. Figs. 16 to 18 are the intricate variations of the tulis type of fish corrals.

The catch of tulis fish corrals comprises shrimps, crabs and other littoral species that come in with the water at high tide.



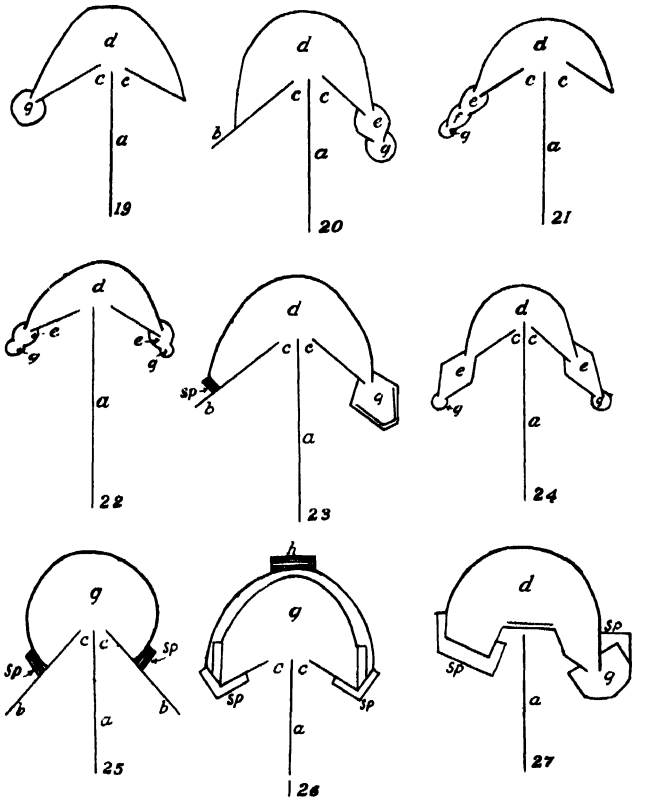
Figs. 1 to 9. Various types of Aguila or Pahubas. (a) leader, (b) wing, (c) gate or entrance, (d) first enclosure, (e) second enclosure, (f) third enclosure, (g) fourth enclosure.



Figs. 10 to 18. Various types of Aguila or Pahubas. (a) leader, (b) wing, (c) gate or entrance, (d) first enclosure, (e) second enclosure, (f) third enclosure, (g) fourth enclosure, (h) collecting crib, (sp) special platform.

Inangcla

This type of fish corral (Figs. 19 to 24) derives its name from the word "angkla", Spanish for anchor, as the general form is that of an anchor. The main features are a

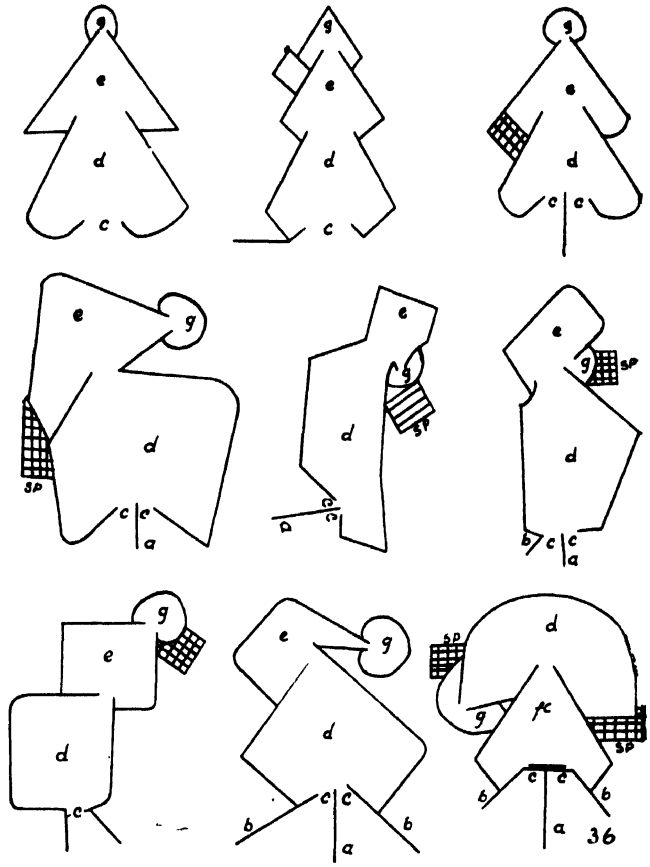


Figs. 19 to 24. Various forms of Inangcla. Figs. 25 to 27. Various forms of Paugmad. (a) leader, (b) wings, (c) gate or entrance, (d) first enclosure, (e) second enclosure, (f) third enclosure (g) collecting crib (sp) special platform, (h) hut.

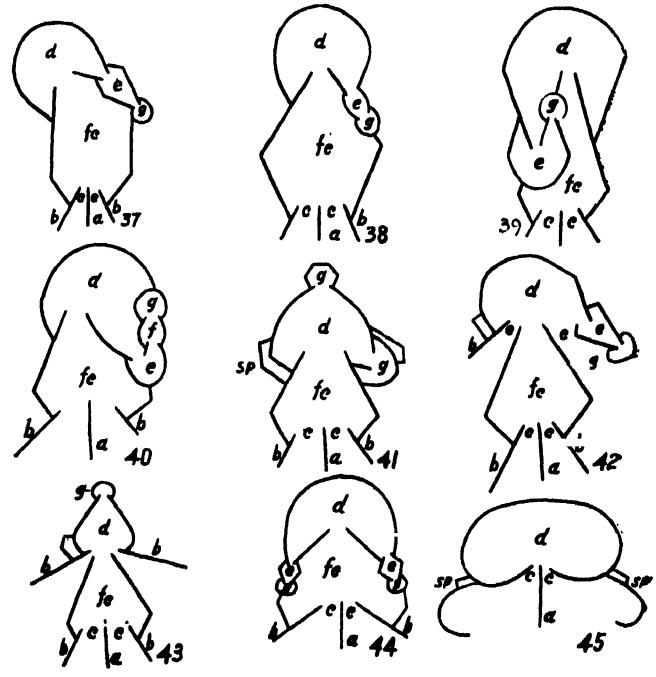
single semi-circular compartment and a leader which corresponds to the shank of the anchor. The variations in inangcla fish corrals are in the shape, size and position of the collecting crib. They are operated both in shallow and deep waters. The corral shown in Fig. 19 is operated in Ragay Gulf by fishermen from Cavite Province while that illustrated in Fig. 20 is widely used in the Philippines, in waters ranging from 2 to 8 fm deep. Fig. 21 shows an inangcla type with a series of small heart-shaped compounds used in Cebu Province in 1 to 5 fm of water. The trap illustrated in Fig. 22 is constructed with small heart-shaped compartments on the tips of both arms, topped by a semi-circular collecting crib, while that in Fig. 23 features a special platform and a wing extension at the tip of one arm, and a diamond-shaped collecting crib on the other.

Paugmad

This type (Figs. 25 to 27 and 45) represents the simplest fish corral in the Philippines. The gear is usually constructed in 7 to 12 fm of water. The special features of this type are a landing platform and a small hut on one or both sides of the enclosure where hauling of the fish is done. Pelagic as well as demersal fish are caught.



Figs. 28 to 35. Various types of Bungsod Zamboanga. Fig. 36. Hasang. (a) leader, (b) wing, (c) gate, (d) first enclosure, (e) second enclosure, (g) collecting crib, (sp) special platform.



Figs. 37 to 44. Various types of Hasang. Fig. 45. Paugmad. (a) leader, (b) wing, (c) gate or entrance, (d) first enclosure, (e) second enclosure, (fc) forechamber, (f) third enclosure, (g) collecting crib, (sp) special platform.

A New Fish Trap Used in Philippine Waters

Abstract
Of the many types of fish traps used for catching fish in sheltered waters of the Philippines, the *new hasang moderno* is considered to be the most effective. Like the other fish traps, this gear consists of a series of enclosures with a leader, four wings, and three entrances or gates. It differs, however, from its prototype (*hasang moderno*) in that the terminal pond is located at the same axis with the leader on the outer side of the semi-circular enclosure which it superimposes. The multiple entrances, together with the leader and the series of enclosures, effectively prevent the escape of the fish which are intercepted. The method of construction and operation of the new hasang moderno is described in this paper and is fully illustrated. Complete specifications of this gear are also discussed.

Une nouvelle trappe utilisee dans les eaux des Philippines

Résumé
Le nouveau *hasang moderno* est maintenant considéré comme engin tres efficace parmi tous les autres types de trappes a poissons utilise dans les eaux abritees des Philippines. Tout comme les autres trappes à poissons, l'engin consiste en une serie de chambres, une queue, quatre ailes et trois entrées. Il diffère cependant de son prototype (*hasang moderno*) par le fait que le corps extérieur est sur le même axe que la queue, à l'extérieur de la chambre semi-circulaire sur laquelle il est superposé. Les portes multiples avec la queue et la série des chambres, empêchent les poissons de s'échapper une fois interceptés. La communication décrit la méthode de construction et d'opération du nouveau *hasang moderno* et fournit aussi des détails très précis de l'engin.

Nueva trampa de pesca empleada en aguas de las Filipinas

Extracto
De las muchas trampas de pesca empleadas en aguas protegidas de las Filipinas, el *nuevo hasang moderno* se considera como la más eficaz. Como las demás trampas, ésta consiste en una serie de corrales como una rabera, cuatro pernadas y tres entradas, pero difiere del prototipo (*hasang moderno*) en que el corral terminal está superimpuesto. Las diversas entradas, junto con la rabera y la serie de cámaras, impiden que escapen los peces que se interceptan En esta comunicación se dan detalles completos e ilustraciones de los materiales, construcción y funcionamiento del nuevo *hasang moderno*.

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PRIOR to the development of the *new hasang moderno*, the *hasang moderno* (Fig. 1) had been considered the most effective. This consists of three gates, *m*, *se*, and *s'e'*; four wings, *w*; a leader, *l*; a series of four enclosures, a heart-shaped terminal pound, *tp*, constructed at the end of one of the arms of the semi-circular enclosure, *si*, which is superimposed by a triangular compartment, *tc*, and a triangular forechamber, *fc*. It has, however, been improved through simpler design and construction, giving rise to the new hasang moderno. This new type was first operated in Kalibo, Capiz, from 1 April 1950 to 15 October 1950. The experiment was so successful that many other parts of the Philippines adopted its use.

General description

Fig. 2 shows its plan. Like its prototype, it consists of a leader, AB; two lower wings, CE and XZ; two upper wings, JH and TV; three gates, EX, GH, G'T; a forechamber, DFGG'WY; a semi-circular enclosure, IKSRK'UT; and a terminal pound, LMNOPQ. The terminal pound, however, is located at the same axis with the leader at the outer side of the semi-circular enclosure which it directly superimposes.

The leader of a typical new hasang moderno is 240 m long and the lower and upper wings are 44 m and 42·50 m long, respectively. The forechamber is 44·60 m at its greatest width, FW, and 31·55 m long, measured from the lower gate to the entrance of the semi-circular enclosure. The latter is also 44·50 m wide, KK', and 26·90 m long, measured from midpoints of GG' and SR, while the terminal pound is 8·90 m, MP, and 8·20 m

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Bungsod Zamboanga

Figs. 28 to 34 show the various forms of fish corrals called bungsod, operated in Samboanga waters 5 to 7 fm deep. The common characteristics are the triangular or quadrangular enclosures, a semi-circular or heart-shaped collecting crib, wings, leader and special platform, all irregularly arranged. The catch comprises both demersal and pelagic fish especially tuna, sardines and mackerels.

Hasang

This type of fish corral (Figs. 37 to 44) is installed in waters 3 to 15 fm deep. Its characteristic feature is a forechamber apart from the regular one or several enclosures, a collecting crib, two or more wings, one or more gates, a leader and one or more landing platforms. The forechamber is either rectangular, triangular or diamond in shape and is called hasang in the Visayas, meaning "gill", from which the name of this type of fish corral was derived.

Fig. 36, the *bolonan* of Capiz, is the simplest form of hasang. Fig. 37, the *hasang antiguo*, has a rectangular forechamber, one gate, a leader, two wings, a semi-circular enclosure, a triangular compound and a heart-shaped collecting crib.

Fig. 41 represents a *bolonan ordinario*, an improvement of the bolonan, showing two collecting cribs. Fig. 42 illustrates the *hasang moderno*, an improved hasang antiguo with three gates and three wings that increase the intercepting capacity of the gear. Fig. 43 represents the hasang moderno as developed in Kalibo, Capiz. This type has been found to be the most effective fish corral in the Philippines. It differs from its prototype in that it has four wings, a terminal type of collecting crib on a straight line with the leader.

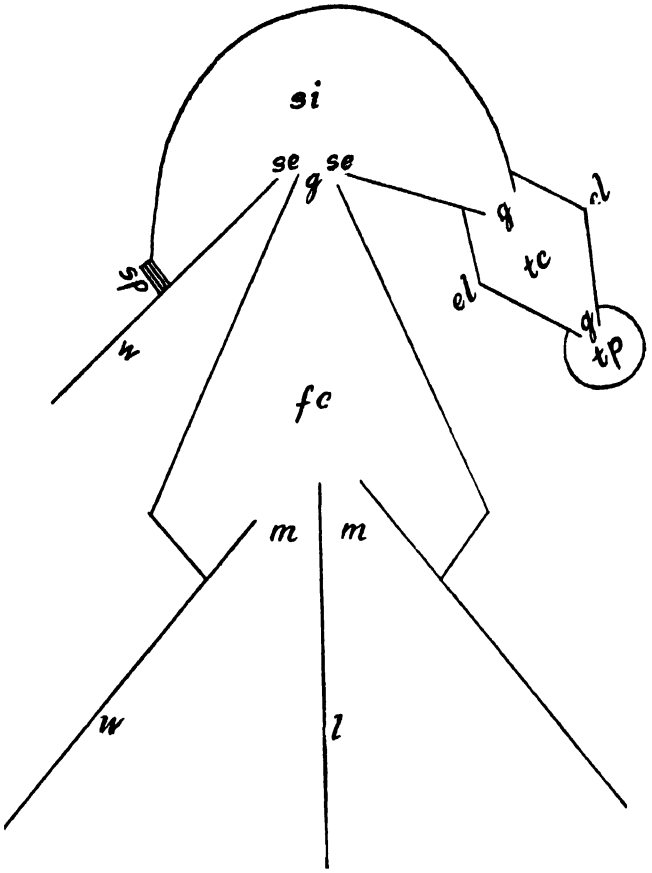


Fig. 1. Hasang moderno (1932). (g) entrance, (e) leader, (m) gate, (w) wing, (el) elbow, (fc) forechamber, (se) side gate, (si) semi-circular compartment, (tp.) terminal pound.

long measured from the mouth of the semi-circular enclosure SR to Side NO.

The fences of the fish trap consist of frames and bamboo screens. The frames (Fig. 3) consist of well-seasoned bamboo posts and braces. The bases of the posts are pointed and triangular holes are bored just below the nodes for the water to fill in the internodes, thus making it easy to plant them at the muddy bottom.

The bamboo screens (Figs. 4 and 5) consist of bamboo splits laced together at regular intervals with either threaded coconut inflorescence bud scales, rattan (Calamus spp.) or *hagnaya* (Polypodium spp.). Table I gives their specifications. As the depths of the bamboo screens are shallower than the depth of the water, two or more are joined perpendicularly end to end to fence the entire column of water. The screens for the leader, wings and forechamber have slats coarser than those for the semi-circular enclosure and terminal pound.

The screens are grouped according to their placings. Those that go together are joined lengthwise, and then rolled like mats to facilitate handling.

Before setting the ground will have been carefully mapped out and all materials prepared.

Construction and setting

The gear is invariably set in sheltered waters with sandy or muddy bottoms free from coral reefs and from 5 to

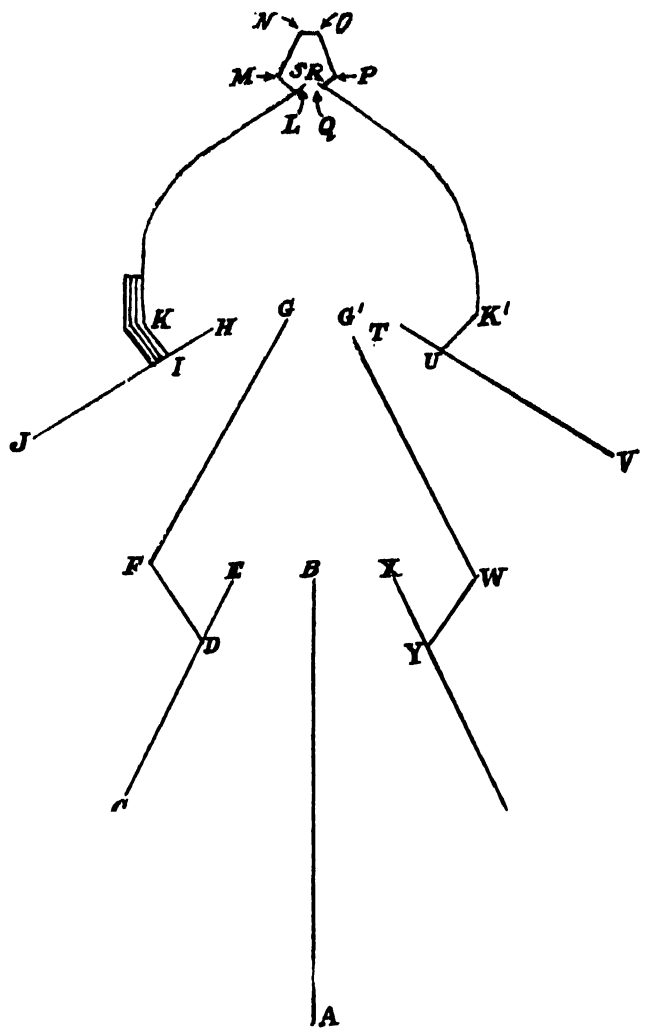


Fig. 2. The new hasang moderno: AB leader, CE and XZ lower wings, JH and TV upper wings, EX, GH and GT gate, DGGG'WY forechamber, IKSRK'UT semi-circular enclosure, LMNOPQ terminal pound.

12 fm deep. Usually, waters shallower than their surroundings are preferred.

The outline-plan of the fish trap (Fig. 2) is carefully plotted by imaginary lines and temporary stakes. The leader is laid perpendicularly to the direction of the current or the shoreline; its length depends upon the distance of the corral to the shore. Generally, the end

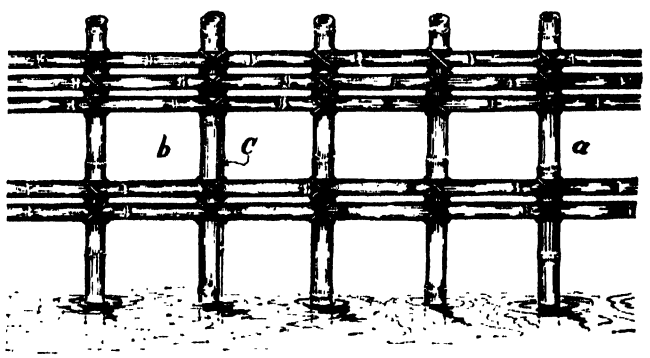


Fig. 3. The uprights or frames. (a) uprights, (b) braces, (c) a bundle of two bamboos.

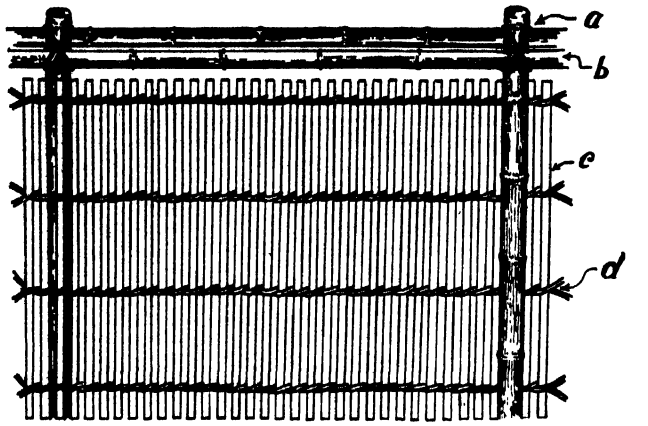


Fig. 4. Portion of the terminal pound and semi-circular enclosure showing lacing of the slats. (a) uprights, (b) brace, (c) bamboo screen, (d) lacing.

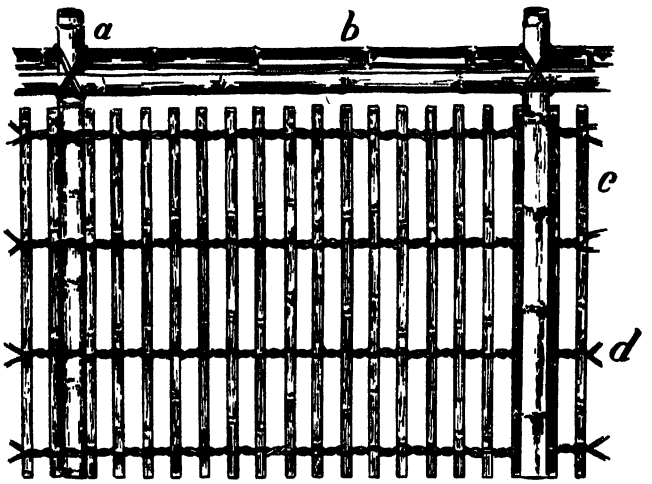


Fig. 5. Portion of the bamboo matting used at the wings, forechamber and leader, showing how the slats are laced. (a) bamboo post, (b) brace, (c) bamboo screen, (d) lacing.

of the leader reaches very near the shoreline. In this setting the master fisherman directs several good divers and other helpers.

The posts are planted at low tide—guide posts first, next anterior and posterior ends of the leader and wings, then the ends and corners of the different chambers. The planting of the other posts follows by setting them at 2 m apart at the semi-circular enclosure and terminal pound; 3 m intervals at the forechamber; and 5 m between them at the wings and leader. Care is taken to make them stand perpendicularly to the water. To strengthen the hold at the bottom and prevent the posts from reclining due to wind and wave, bundles of bamboos (Fig. 3c) or long coconut trunks are used for every fourth post. Two to four lines of bamboos are braced to connect each pole just above the bamboo screens. The whole set of the bamboo poles constitute the framework of the fish corral.

The setting of the bamboo screens follows the completion of the frame. A stone weight of about 15 kg is tied at the lower end of every rolled screen to keep it standing erect. The screen is unrolled little by little and tied with the rattan splits, hagnaya, or threaded coconut inflorescence bud scales to the framework.

The setting of the screens is usually begun with the terminal pound followed by the semi-circular enclosure, then the upper wings, forechamber, lower wings, and lastly, the leader. This order is followed because fish often begin to enter the enclosures as soon as they are set.

Unless destroyed by gales or typhoons, the fish trap may last from six to ten months. Its upkeep, however, requires periodical changing of the screens whenever they become weak or when they need cleaning and drying. Hence, there must be a reserve of at least one-half of the total number of screens. When the season is over, all screens are removed, leaving the framework for the next season. The screens are scrubbed, dried and repaired for next season.

The nets

Two nets are used to catch the fish—the scoop seine (sigin) for the semi-circular enclosure, and the shrimp net at the terminal pound.

A diagram of the scoop seine appears in Fig. 6. Tables II and III give its specifications. It consists of a bunt (Fig. 6A, B) flanked by two wings (Fig. 6C, D)

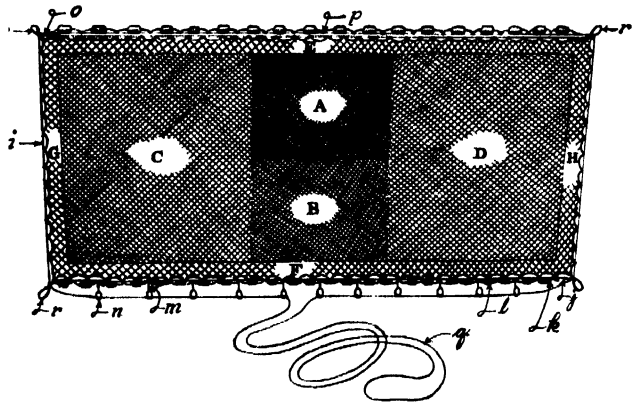


Fig. 6. Structural plan of the sigin. A, B, C and D wing; E, F, G and H selvages; i breastline; j secondary leadline; m bridle; n ring; o secondary floatline; p primary floatline; g pursing rope; r eye splice.

hung on a headrope 27·10 m; a footrope, 22·50 m and a breastline 12·20 m. Each wing is made of 9-thread cotton twine netting of 2·5 cm mesh-stretched, 573 meshes wide and 800 meshes deep. The bunt is composed of two nettings, the upper portion of which is 312 meshes wide and 500 meshes deep, 2·5 cm mesh-stretched and made of 12-thread cotton twine; while the lower portion is a 9-thread cotton twine netting, 2·5 cm mesh-stretched 312 meshes wide and 300 meshes deep. These are joined mesh to mesh.

Fig. 8 is a diagram of the shrimp net. It is in the form of an isosceles trapezoid and made of several pieces of sinamay cloth sewn together. This is hung to a manila rope, 1·3 cm in diameter, with 40 per cent slack, by a 9-thread cotton twine. The finished shrimp net measures 7·70 m and 3·40 m on its parallel sides, while each of the nonparallel sides is 8·40 m.

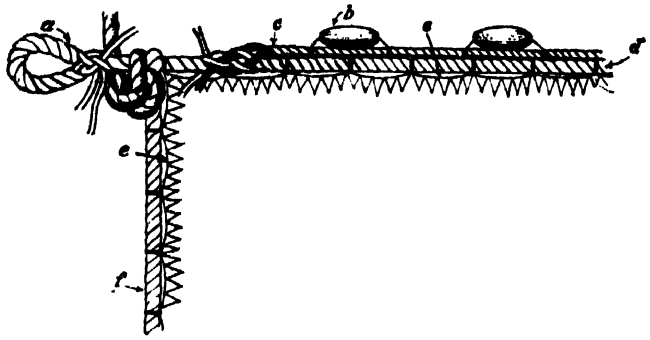


Fig. 7. Portion of the headline. (a) eye splice, (b) float. (c) primary floatline, (d) secondary floatline, (e) lacing line, (f) breastline.

Like the scoop seine, each end of the hanging line is an eye splice (Fig. 8b) where the pull rope is tied during the operation. On the midpoints of each of the nonparallel sides and at the ends of the longer parallel side GI rings (Fig. 8c) are tied and threaded into the gliding rope when the net is shot and hauled in at the terminal pound.

The following materials are employed in the construction of the shrimp net:

Sinamay cloth: 87·40 m × 1 m.
Manila rope: 30 m × 1·5 cm diam.
GI rings: 4, 0·8 × 7·5 cm diam.
Cotton twine: 50 m, 9-thread medium laid.

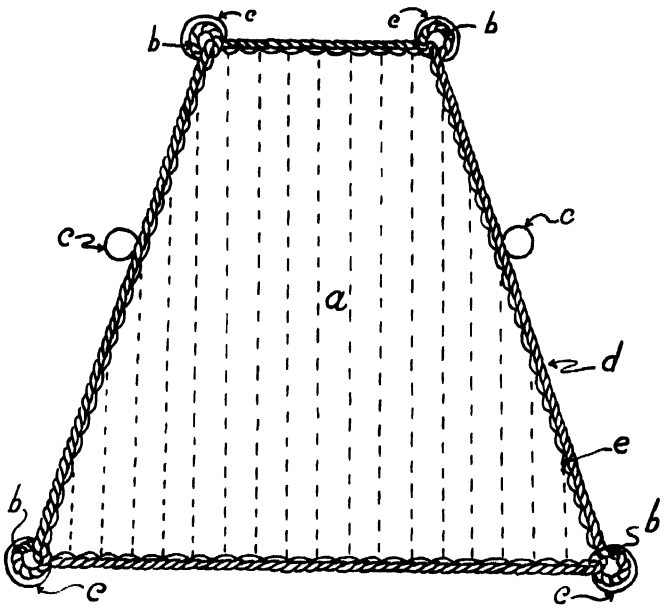


Fig. 8. Structural plan of the shrimp net (not drawn to scale (a) sinamay cloth, (b) sling, (c) GI rings, (d) hanging line, (e) lacing line.

The boats

Two boats are used—the bigger (Fig. 9) for transporting the fishermen and nets to and fro, and the smaller one to carry the catch ashore.

The bigger boat is an ordinary dugout, 14 m long, 1 m wide and 0·50 m deep, with one wooden plank each side. An outrigger on the port side enables it to be brought close to the fence of the corral.

The small boat (Fig. 10) is flat-bottomed.

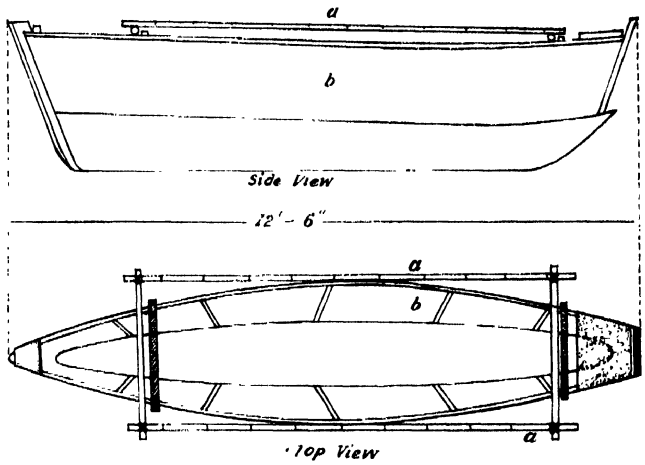


Fig. 10. Lateral and side views of the small boat. (a) bamboo carlocks, (b) planking.

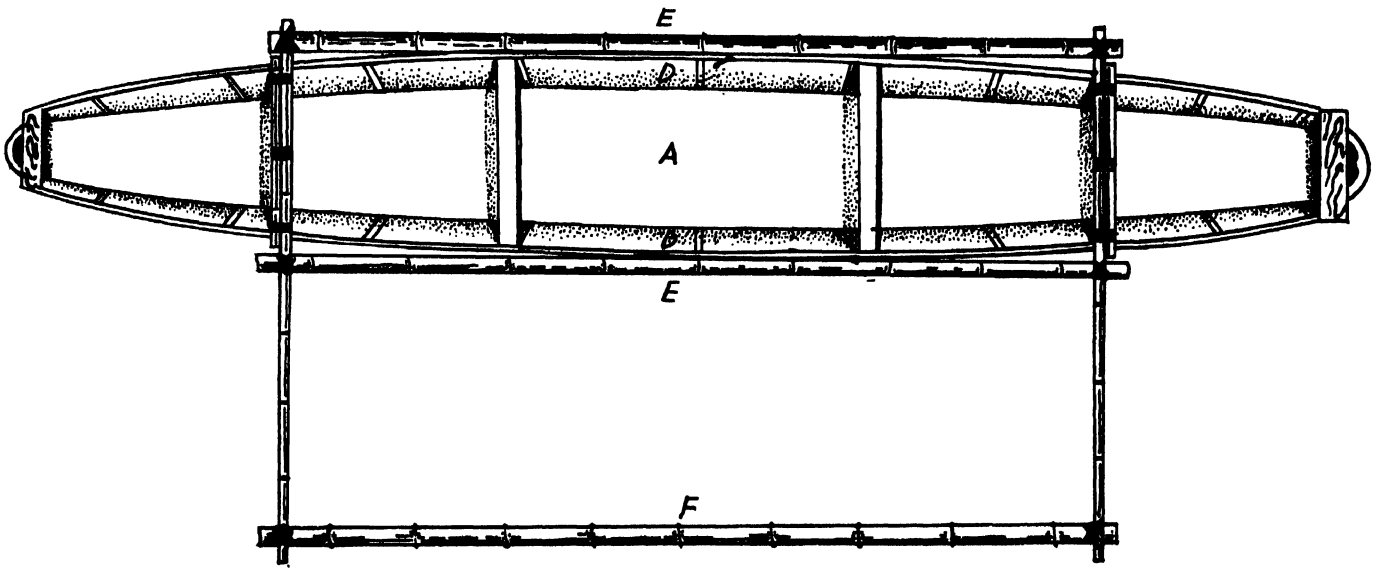


Fig. 9. Top view of the main boat. A. hollow keel, B. bow, D wooden planking. F bamboo for carlocks.

The crew and their duties

A complement of 16 fishermen operates the fish corral: one master, two assistants, four divers and nine ordinary fishermen. The master fisherman directs all the work, including construction, maintenance and fishing operations, and the marketing. The divers construct and repair the gear, and the ordinary fishermen are general utility men.

The splitting of the bamboos, cleaning, lacing or weaving of the bamboo screens are done by contract labour. These expenses are deducted from gross sales before a profit is declared.

The crew is paid on a profit-sharing basis. All the expenses are deducted from gross sales and the remainder is divided into two equal parts. One part goes to the owner of the corral while the other part is divided into 19 shares distributed as follows:

1 master fisherman, 2 shares, 2 assistant masters, 1½ shares each, 4 divers 1¼ shares each, 9 ordinary fishermen 1 share each.

Fishing operation

The catching of the fish is done during early dawn to be sold that morning.

A seven-man crew—one assistant master fisherman and six ordinary fishermen, operates the shrimp net in the terminal pound. Four stone weights of 2 kg each are tied to the four corners of the net. Then gliding ropes are tied at points *e* and *f* of sides AC and BD (Fig. 11)

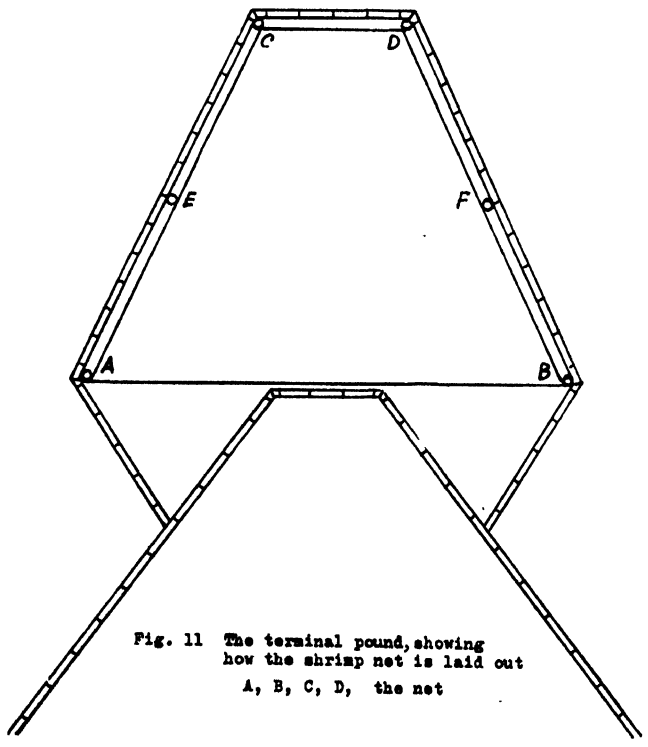


Fig. 11 The terminal pound, showing how the shrimp net is laid out
A, B, C, D, the net

respectively, and perpendicularly down to the base of the frame. To this, each ring (Fig. 8c) is threaded by the corresponding gliding rope, thus allowing the net to glide up and down when setting and hauling. They also serve as supports of the net when set, and keep it from drifting.

In setting the net the eye splices (Fig. 8b) are each tied down with a pull rope while the rings are threaded by the respective gliding ropes. The corners are tied with a stone weight of 2 kg each. Corners C and D (Fig. 11) are brought near points *e* and *f* and dropped to the bottom. The other portion of the net (Fig. 11, AB fe) is also dropped. This is done to prevent fish inside the pound being covered by the net. Then, the pull ropes at C and D are pulled to spread the net so that the bottom of the terminal pound is covered entirely. After a while, it is raised to scoop the catch.

Fig. 12 shows the setting and hauling of the net at the

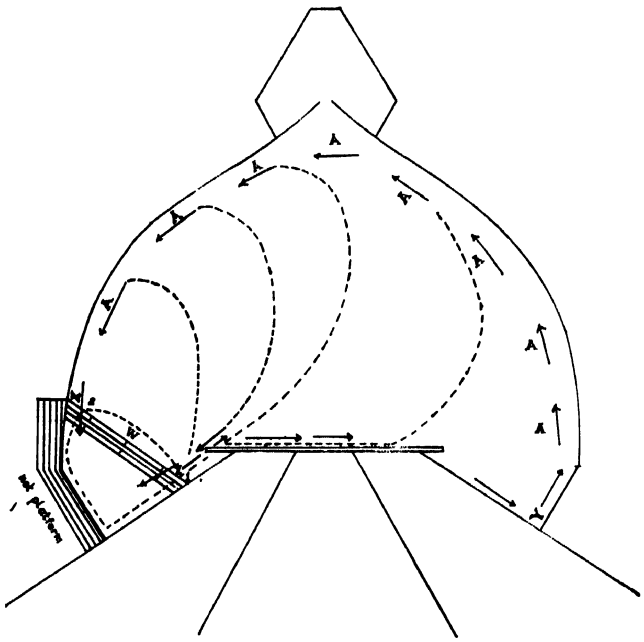


Fig. 12. Setting and hauling of the net at the semi-circular enclosure.

semi-circular enclosure. Nine fishermen, including the master fisherman and one assistant master fisherman, are needed. The net is dropped at the bamboo bridge (Fig. 12W) at X_1 and then extended to Y, thus transforming it into a curtain closing the entrance and gates of the fish corral. The end, at Y, is dragged close to the fence following the direction as indicated by arrow A of Fig. 12 until X_2 is reached. When this has been carried out the four divers see that the leadline touches the sea-bed and the fence of the enclosure. Three men on the bamboo bridge hold the floatline while the leadline is brought close to the fence below the net platform and the bottom of the net is raised by pulling the pursed line, thus forming a sort of hammock. Here the fishes are concentrated at the bunt where they are scooped and placed on the waiting banca. This is repeated several times.

The fish caught comprise most of the pelagic species which are fished on a commercial basis. Shrimps are also caught during the dark phase of the moon, particularly when attracted by a lamp. Catches are sold to fresh fish venders, or to wholesale buyers for salting.

Dropline Fishing in Deep Water

by
Ronald Powell

Fisheries Officer, Rartonga

Abstract
The development of fishing in the Pacific Islands is very restricted owing to the particular fishing conditions. Many of the islands are coral formations rising almost sheer out of depths of 2,000 fathoms so that most of the fishing gears which operate on the world's continental shelves cannot be used. Tuna longlining can only be done from the few islands which can offer adequate harbour facilities. The paper describes the mechanization of handlining in up to 500 fathoms. The $\frac{1}{16}$-inch steel wire lines carry 8 to 10 branchlines with hooks, and are wound on wooden drums. These drums are slipped over a driving shaft which is connected by a friction clutch to a small gasoline motor. The hauling speed is adjusted to about 27 fathoms/min at slow speed, but can be increased to more than double this speed with the engine at full throttle. Up to 12 such drums of lines are set out, anchored by a short length of chain. Five different types of hooks were tried and it was found that the Polynesian hook with its incurving point was superior for this type of handlining as they could catch and hold a 3-lb fish as well as 500-lb sharks. The entire catch was made on the lower three hooks spaced $4\frac{1}{2}$ ft apart while the bait on the upper hooks was never touched, showing that at these depths the fish stay close to the bottom. The experiment has proved that at these great depths there are valuable food fish as *Ruvettus*, *Gymnothorax* and *Polymixidae* as well as large sharks so that there may be a future in this type of deep fishing, operational from small canoes.

Peche a la ligne dans les eaux profondes

Resume
Le développement de la pêche dans les Iles du Pacifique est très restreint par suite des conditions particulières de la pêche. Les îles étant en grande partie constituées par des coraux émergeant de profondeurs de 3750 m, la plupart des engins de pêche utilisés sur les plateaux continentaux du monde ne peuvent être employés ici. La pêche du thon à longue ligne ne peut être pratiquée que dans quelques îles offrant les facilités de port nécessaires. La communication décrit la mécanisation de la pêche à la ligne jusqu'à des profondeurs de 900 m. Les lignes en fil d'acier de 1,5 mm diamètre comportent de 8 à 10 branchons avec des hameçons et sont montées sur des tambours. Les tambours sont glissés sur un arbre de traction qui est couplé à un moteur à pétrole par un embrayage à friction. La vitesse de halage est réglée à 50 m/min pour un régime lent mais peut être doublée quand le moteur tourne à plein. Jusqu'à 12 de ces tambours sont mis à l'eau, ancrés par de courtes longueurs de chaîne. Cinq types différents d'hameçons ont été essayés et on a trouvé que l'hameçon polynésien avec sa pointe recourbée était supérieur pour cette méthode de pêche à la ligge puisqu'il pouvait capturer et retenir des poissons de 1,5 kg aussi bien que des requins de plus de 200 kg. Toute la capture a été produite par les trois hameçons les plus profonds, ceux-ci étant espacés de 1,30 m tandis que les amorces des hameçons supérieurs n'étaient jamais touchées. Ceci prouve qu'à ces profondeurs il existe beaucoup de poissons comestibles de valeur tels que les *Ruvettus*, *Cymnothorax* et *Polymixidae* de même que des requins et permet de penser que dans l'avenir, ce type de pêche à la ligne pourra être appliqué à la pêche commerciale pratiquée avec de petits canots.

Pesca con palangres en aguas profundas

Extracto
El desarrollo de la pesca en las islas del Pacífico está muy restringido e causa de condiciones especiales. Muchas de las islas son formaciones coralinas que se elevan casi verticalmente desde profundidades de 2.000 brazas, por lo que no se pueden emplear la mayor parte de los artes de pesca usados en las plataformas continentales del mundo. La pesca de atún con palangres solamente se puede realizar desde pocas islas que ofrecen buenos puertos. Describe la ponencia la mecanización del halado en profundidades hasta de 500 brazas. La línea madre, de acero de 1/16 pulg de diámetro con 8 ó 10 brazoladas, se arrolla en carreteles de madera que se ponen en el árbol de una transmisión conectada mediante un embrague de fricción a un motor de gasolina pequeño. La velocidad de halado se ajusta a 27 brazas/min con el motor a poca marcha, pero es factible de duplicarse con el motor a toda marcha. Se calan hasta 12 palangres que se fondean con cadenas cortas. Se han ensayado 5 clases distintas de anzuelos y se ha observado que el de la Polinesia con la punta curvada hacia adentro es el mejor porque sujeta peces de 3 lb, así como tiburones de 500 lb. Toda la captura se logra en los 5 anzuelos inferiores, distanciados 4 ó 5 pies, en tanto que el cebo de los superiores está siempre intacto, lo que demuestra que a esas profundidades los peces están my cerca del fondo. La experiencia ha demostrado que en aguas muy profundas se encuentran pesce comestibles como *Ruvettus*, *Gymnothorax* y *Polymixidae*, así como grandes tiburones, por lo que puede ofrecer buenas posibilidades esta clase de pesca practicada desde canoas pequeñas.

THE Pacific Ocean covers half the world's surface. It has an average depth of about 2 miles and less is known about the biology of this vast inner space than is known already about the moon's surface. Until comparatively recent years oceanographers stated that very little life was possible below the level where visible light could penetrate. The islands which dot this vast stretch of Pacific Ocean inside the tropics are generally small and the hundreds of coral atolls of the tropical Pacific rise almost sheer from depths of over 2,000 fathoms. Few areas of shallow water are found where the conventional fishing gear of the world's continental shelves can be used.

While it has long been thought desirable to improve the fishing industries of these island groups the methods of improving subsistence fishing and developing limited commercial fishing pose very special problems not encountered in areas with a continental shelf.

Since the last war the expansion of the Japanese pelagic fishing fleet has left no shadow of doubt that almost unlimited quantities of large fish can be caught by tuna longlines anywhere close to the tropics. This type of operation, however, requires specialized vessels and heavy commercial fishing material beyond the financial means of most island communities, quite apart from the lack of docking, ice making, transport and communication facilities. Any methods of improving the catch rates in shallow lagoons threaten the extinction of local stocks in comparatively short time.

Development must then be directed towards deep-water using a suitable method of fishing which would be within the reach of the financial resources of the local fishermen; operational from the presently used type of boat as well as such types which could in the immediate future be operated from the Pacific islands; operational with the type and supply of bait available in the islands.

While trolling does occasionally produce good catches, it could not be developed into a regular fishery due to the short season during which fish are available. Drift-netting has been tried but damage to the nets has proved it to be uneconomical. Longlining has a future in the

island fisheries but as it requires a minimum of 20 to 30 baskets for commercial operation it is doubtful whether it would be economic with the present size of boats.

This leaves only handlining which is a well known fishing method in the islands of the Pacific.

Traditional handlining

The Polynesians learned to catch fish in the deep waters with handlines ages ago and their wooden Ruvettus hooks which are quite part of their culture gradually developed from the peculiar fishing conditions, and the local means available to meet them. Operating handlines down to 500 fathoms depth on or near to the bottom, as practised around the Pacific islands, raises many different problems. The boat generally rises and falls over a long ocean swell which means that in fine weather the line is tightening and slackening as each wave passes, so that it is most difficult to feel a fish bite even if this could be done over such a long line. With cotton lines it is nearly impossible to jerk or strike the hook when a fish bites—not only because of its elasticity but also because of the curve the line normally takes in rising to the boat. This can be partly overcome by attaching a sinker to the line but this then causes the problem of lifting such a sinker which has to be done many times in a night's fishing. To overcome this the Polynesian fishermen have developed several ways of attaching stones of about 14 lb which can be released when the hook touches the bottom or when a fish strikes. Under these conditions the Polynesian fish hook with its incurving point was developed, but only produced good results when used with the technique for which it was designed.

The hook depends on rolling through part of a circle when pressure is applied to the point and operates so that when the fish seizes the bait the hook is swallowed to the back end of the mouth while the fish moves off with a trailing line. If the line is struck at this time, the hook will be pulled out of the mouth easily. If, however, the fish is allowed to move off with the leader trails behind, the fish will at a certain moment pull against the tightened line, pulling the hook down into the corner of its mouth, or the top edge of the jaw is forced between the hook's shank and its point. If the line is kept steadily taut at this position the fish will change direction so that it swims at right angles to the line. In this position all the pressure bears on the hook's point and it rolls through a part circle coming out very often through the top of the head or the side of the jaw. This is, in fact, the only disadvantage of this type of hook in that very often it is necessary to cut the hook out as there is no other means of disengaging it. Once a fish is taken on these hooks it is rare that they can disengage themselves. On the other hand, they would be inefficient where speed of unhooking is an important factor in the operation.

The Polynesians operate two to three lines simultaneously from their canoes and while fishing they paddle to keep the canoe as much as possible over the lines which is a difficult and back-breaking job.

Each cotton handline is tapered towards the hooks by using a decreasing number of threads in making up the line to ensure that if the hooks snag in the coral bottom the line will break well down. The lines carry two to five hooks and this is a constant danger as a large fish on the bottom hook may drag out the already hauled snoods causing serious accidents when the outrunning hooks catch any part of the fisherman's body or even his clothing.

New method

It was clear that any development of this fishery had to be adjusted to the boats available and within the financial means of the fishermen. This already restricted the scope considerably but it was decided to try mechanizing the operations by developing a simple power gurdy which would permit the operation of several lines at the same time.

As handlining from the canoes themselves would restrict the number of lines that could be operated to two or three, and to avoid the danger of entangling lines when hauling a large thrashing fish, it was decided to anchor the lines out individually. This could be done by having them coiled on a floating drum which could itself be slipped on the power gurdy shaft for hauling.

Power gurdy

A gurdy was designed that could be constructed from locally available material and driven by a small gasoline engine. The drive was made through a worm wheel and pinion.

Tests had shown that for hauling large fish a hauling speed of 8–9 fathoms per minute would be the most appropriate, and the drive was calculated to obtain this speed with the engine running at 450 rpm. With the engine running at 1500 revolutions at full throttle the hauling speed was nearly 30 fathoms per minute. The gurdy shaft included a spring loaded friction clutch which could be adjusted so that it would slip at an overload, to avoid breaking the lines on struggling fish. This system (illustrated in Fig 1) worked so well that several sharks of over 500 lb were hauled on wire snoods having a breaking strength of only 185 lb. This was possible by setting the clutch so that it reversed when the fish brought on too much tension. The load spring was set in a square hardwood block which pressed the block against the shaft shoulder providing the required friction.

Drums

The drums were constructed as shown in Fig 1. They were of marine plywood with a soft wooden core, 16 in in diameter and capable of holding 600 fathoms of $\frac{1}{4}$ in wire. The drum core had a $2\frac{3}{4}$ in square hole in the centre which could be slipped over the square block of the gurdy. During the first few trials a revolution counter was mounted on the gurdy to assess the length of line out as each turn on the drum was on average 3 ft

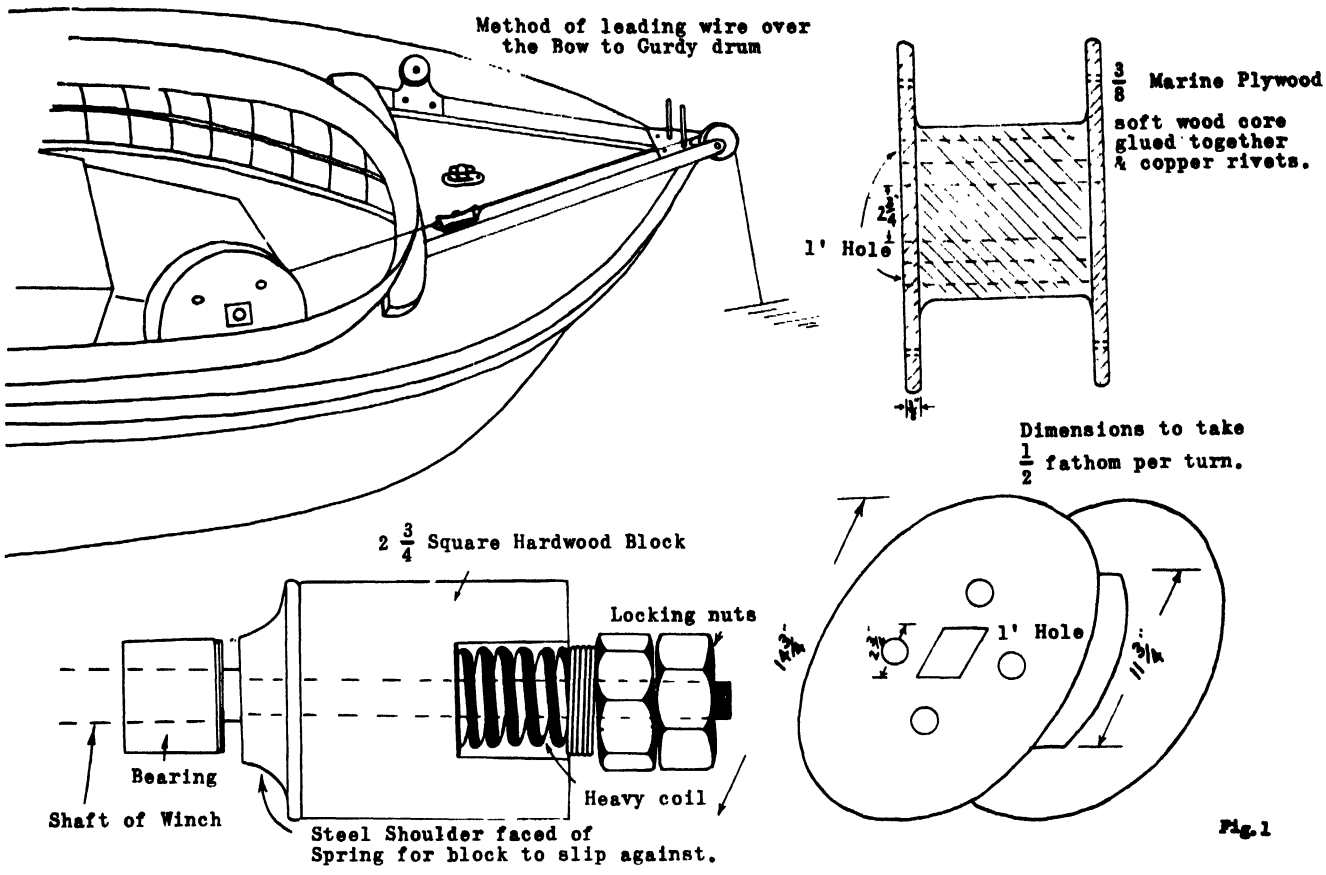


Fig. 1

long, but this was later disregarded as it was found easy to judge the length of line left on the drum.

The gear

The lines were $\frac{1}{16}$ in steel wire having a breaking strength of about 200 lb; however, it was found during the experiments that a line of about 350 lb breaking strength would be easier and safer to work the larger fish. The lines were marked at several places with pieces of white cotton to give warning, especially at night, of the approach of the snoods to the fairlead.

Eight to ten snoods of 14 in length were used with spreaders and swivels attached, as illustrated in Fig 2. Swivels were furthermore inserted at every 100 fathoms in the main line to avoid spinning of the baits as the line is lowered to the fishing depth.

As the lines were to be operated individually, and to avoid them drifting from the bottom slope into deep water, they were anchored and this was at first done by 15 lb stones. These stones, however, were found to slip down the steep bottom slope, so they were later replaced by about 2 fathoms of $\frac{3}{8}$ in chain, which gave excellent anchoring results.

Hooks of five different sizes and varieties were tried, including three sizes of incurving tuna hooks of a special design and of these, sizes 1, 3 and 5 gave the best results. Japanese tuna longline hooks size 2/0 were also used. Fish as small as 3 to 4 lb were caught on the same hooks which hauled 500 lb sharks, especially with the Polynesian type of hooks.

Results obtained

The gear was completed in March 1961 and the first trials were made off Black Rock, to the north-west of Rarotonga, during daylight. The area is on the leeside away from the prevailing south-east trade wind, and depths of 1,000 fathoms are reached at less than 1 mile offshore. Twelve drums complete with lines, snoods and hooks were carried, each drum having two yellow plastic floats to assist in buoyancy, and also to act as a damper to the wave-surge. It was found that the yellow plastic floats were well visible during daytime. At night the floats carried a small battery-operated light so that no problems of finding the gear were experienced except during a few heavy rain squalls when the visibility dropped to nil.

The lines were set out in a V-pattern covering a depth of 100 to 500 fathoms, and as the anchoring stones resulted in some of the lines drifting, 2 fathom lengths of chain were substituted and no further trouble was experienced.

In spite of the forebodings of the local fishermen no trouble was experienced in operating the drum-wound steel wires, picking up the gear, mounting it on the gurdy, and hauling; even the big 500 lb sharks raised no problems whatsoever.

In setting, the wire was allowed to run out from the drum until the chain reached bottom, the wire remaining on the drum was then stoppered and the drum simply cast over-board with its floats attached. To avoid the danger of hooks running out when a large fish is on one of the bottom hooks, a fork was installed at the stem consisting of a bronze rod lined with hardwood through which a narrow sawcut had been made; as each snood was hauled aboard it was dropped into the sawcut so tha if the line should run out, it would stop when the first hook reached the fork. (Fig 1).

On hauling large fish, such as sharks, as soon as they come near to the surface, the friction on the clutch was reduced to well below the breaking strength of the snood and the line carefully hauled until the fish came alongside. Once the fish was killed it was taken aboard, or if too large for this, towed astern by a rope attached to the tail.

While good results were obtained with the hooks described above, it was clear that the use of more Ruvettus hooks would probably have given even better resultes However, the construction of such hooks requires suitable natural-grown crooks of hardwood which are difficult to find. The peculiar conditions of such deep water handlining require a different function from that of hooks used in shallow water. When a large predatory fish is hooked in the soft part of the jaw, they break away easily. The Ruvettus hook is normally swallowed to well back in the mouth where it strikes a region normally including some part of the bone structure; fish are therefore seldom lost with these hooks. It would be interesting to see whether metal hooks constructed on the same principle would be an improvement for bottom-set longlines, especially in fisheries where relatively long snoods are used and where the same conditions of slack lines and slow hooking exist.

The experiment brought to light some interesting biological matters. The catch of *Polymixidae* shows that there must be other fish feeding on bottom as its two long barbels show that it is fully adapted to bottom feeding. Unfortunately, none of the fish yielded any stomach contents other than the bait used. Large sharks were caught which are seldom seen near the surface off Rarotonga. For many years the fishermen of Rarotonga had wondered what kind of fish fed on the bait thrown out during fishing for yellow-fin tuna with a fleet of sometimes 50 canoes; the experiment indicates that a sizeable fish population on the bottom takes care of it.

Several species of valuable food fishes were brought up which had never been caught before in these islands and are, in fact, rare in other parts of the world. The presence of *Etelis marshii* and *Etelis carbunculus*, which are two of the most beautiful fish in the oceans, was a pleasant discovery, as these are apparently only caught on rare occasions. On one occasion a silver eel (*Anguilldae*) was caught and it was rather surprising to find that it swims and feeds as deep down as 500 fathoms. *Gymnothorax spp* was a common part of most catches. These fish are normally associated with particular types

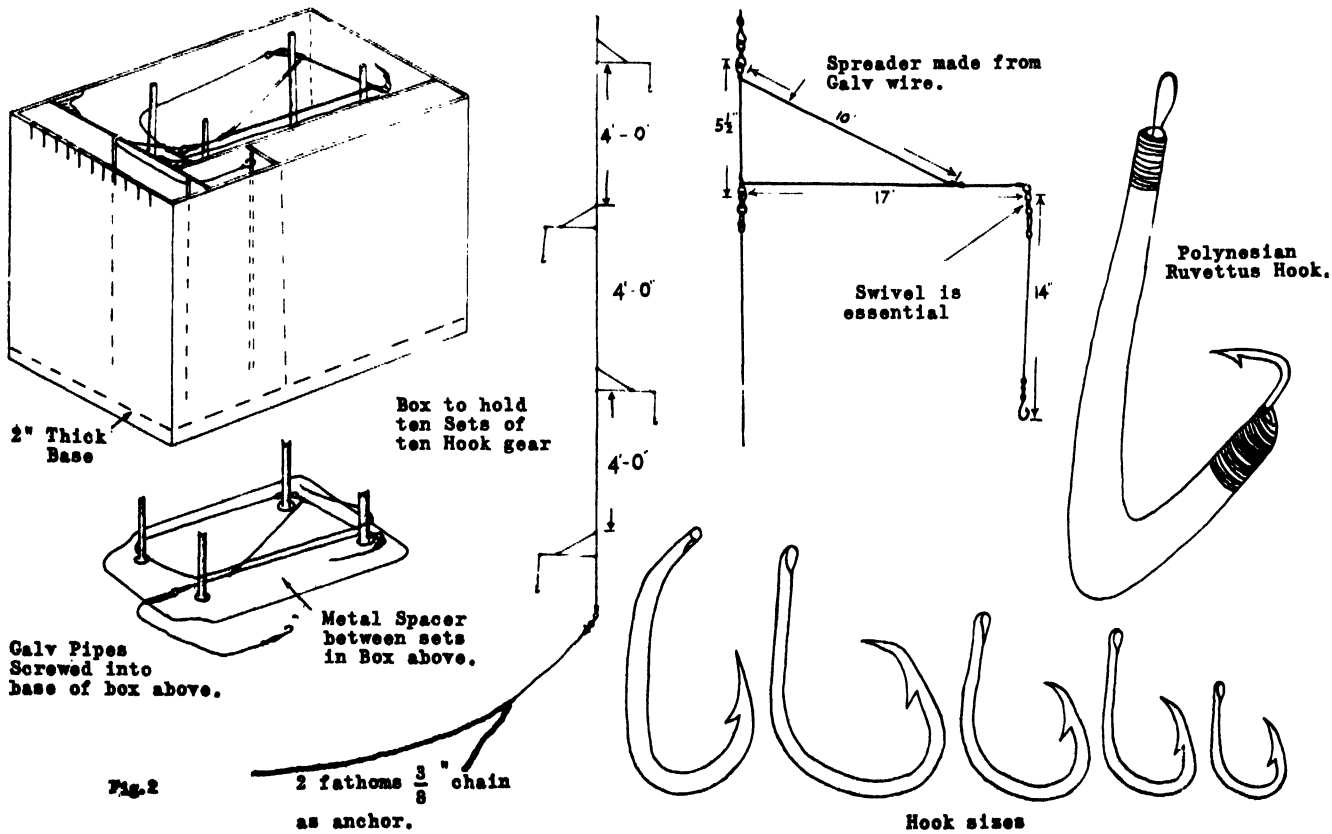


Fig.2

of coral near which they live and feed, and it would be interesting to know whether such an environment is present at such great depths or whether they change their pattern of living.

Ruvettus has, of course, been caught on these islands for centuries and was a common catch. It appears to rise for feeding to about 100 fathoms on dark nights but certainly seems to feed lower than this at other times. This would seem indicated by its peculiar luminous eyes which are obviously adapted to live at an extremely low light level. Many of the fish caught were preceded to the surface by bursts of air or gas from the swim-bladders and usually offered little resistance. Sharks, however, and Ruvettus still fought hard even when the snood had reached the boat.

Practical fishing with this gear has shown that there is more fish available between 350 fathoms and 500 fathoms depth than in the shallow regions. A further remarkable fact is that nearly all catches were made on the bottom three hooks while the baits on the top five hooks were never touched; this clearly indicates that the fish at this depth are mainly bottom feeding species.

Further trials with slightly adapted gear will be carried out in deeper water.

J. Frechet

Discussion on Gillnetting Longlining, etc.

Mr. Jean Frechet (Canada) Rapporteur: Drift and gill-netting activities are vastly important the world over. Masatake Neo describes how 12,000 Japanese fishermen worked for two months in a mothership operation in the North-West Pacific harvesting salmon. Under the Russo-Japanese convention, driftnets totalling nearly 10,000 km can be set and 369 driftnetters were so employed in 1962. After nine hours' fishing at night the catches were delivered daily to the mothership. One-third of the nets was made of monofilament polyethylene while the remainder was of multifilament nylon. The hanging ratio of the nets does not appear to be regulated and I would appreciate knowing why the Japanese fishermen hung their nets with a ratio of 45 per cent when it is understood that much more efficiency would be derived from a hanging ratio slightly under half the measure of the stretched length. This paper is highly informative on the technique of transferring catches.

The haulers in the driftnet salmon operation are described by Miyazaki. Three main types of net haulers have been developed and use of them has more than doubled the net hauling capacity of the fishermen. Many net haulers have been developed all over the world to reduce hand labour, but that hand labour still remains the most widely used source of fishing energy. However, great progress is being made in mechanisation. Kuraptsev of Russia particularly described that country's progress. Many hundreds of vessels have been equipped with a complete set of net or fish handling machinery. Their range of mechanisation includes a net driving roller on the bulwark which can be tilted inboard when necessary, a net hauler with separate vertical gurdies working on the North American Crossley principle of spring activated teeth gripping the lines over half the circumference of the head, a warp shock absorber protecting against excessive strains in bad weather, a machine to shake the fish out of the nets, a fish and salt mixing conveyor and vibrating barrel platform capable of packing three to four tons an hour, a 2,000-fathom warp stowing machine coupled to a warp storing drum, some overboard net and warp leaders to shoot the nets well out from the vessel's side and to prevent fouling the propeller, and, finally, a retention guide to ensure a regular flow of webbing. There is also a remote reading sea water thermometer to make sure that the nets are set in an adequate habitat. Such mechanisation gives easier and speedier fishing.

An interesting Canadian experiment with Japanese monofilament gillnets in inshore waters showed that when cod-fishing at 20 to 50 fathoms in both clear and dirty waters, results are always better than with multifilament. Their catch was from three to ten fold greater. Comparative results from other fisheries would be interesting.

In relation to longline Hirano details the measures developed by the Japanese for learning the configuration of the lines at certain depths related to the presence of fish. Echo sounders using the high frequency of 200 kc have been found most effective and gave better results than pressure gauges.

Technical developments which permitted the use of polyethylene or 'Kuralon' longlines of 750 kg tensile strength are described by Tominaga in his paper on mothership longline fishing in the Bering Sea. In this connection Canada had developed a braided longline and gangings to meet successfully the needs of fishermen for an improved longline.

In the Philippines fish corrals or traps were much used and Roldan and Rasalan outlined a great number of types under seven distinct headings while Rasalan gave a more elaborate description of the most effective of these fishing corrals—the hasang moderno. This trap consists of a series of enclosures with a leader, four wings and three gates.

In describing the Mediterranean and Atlantic tuna traps Fodera tells how the Sicilians had introduced a new chamber between the death chamber and the body of the trap so as to combine the advantages of both types.

Although tanglenets and trawlers are used in catching crabs in Alaskan waters, the most successful modern method described by Allen is to use big pots, if round with a diameter of six feet, or square with seven-foot sides and two and a half feet high. These last weigh 250 pounds each, were covered with soft stainless steel wire in squares and have tunnels on opposite sides. A good catch was 50 crabs per pot but they sometimes got 100. On these craft, 40 to 150 ft long, hydraulic winches are necessary. New requirements listed by Allen constituted a challenge to technologists and engineers; a new design of buoy, line-coiling machines, mechanical unloading devices and means of scouting for crabs.

Dr. Miyazaki (Japan): On the hanging ratio question said: For merely getting the fish into the meshes about 30 per cent hanging-in is quite adequate, but if you want to entangle them, the hanging-in should be between 40 and 50 per cent or even more than that; therefore, if you want both gilling and

entangling at the same time a 40 per cent ratio would be appropriate. This is based on my experience in using drift-nets.

Mr. R. D. Leakey (U.K.): Many new inventions are needed to facilitate longlining, gillnetting and trapping. As regards longlining, very little research is being done to develop a scoop for bringing the fish from the water to the boat rapidly without having to gaff them when you are getting large catches. There is also the question of bait protection. There has been developed in this country a very fine polythene net in the form of a sausage which protects the bait from predators and vermin, and once bitten by fish they cannot spit it out as the fine meshes entangle in their teeth. Quickly detachable snoods could save time wasted on removing the fish from the hooks in heavy fishing and also allow stowing of the line in such a way that the hooks could be easily rebaited on board. Folded traps for lobsters and crabs had been available in Britain for six years but were not much used because of price. They could, however, certainly give Canadian and others useful points in relation to them once they had been scaled-up to their requirements.

Mr. Davidson Thomas (India): Gillnetting is very important to us in India. Our experiments with bottom-set nets and drift-nets, showed that gilling must be partly combined with entangling. This is because of the varying size and velocity of the tropical fish. In bottom-set gillnets we use a hanging ratio of about 50 per cent which gives scope for entangling as well as gilling. We get the best results if three or four meshes are allowed to ride loose on the framing lines between points of attachment. In sardine fishery we hang the webbing mesh by mesh hung in a little less than 50 per cent for gilling rather than tangling. For materials they had tried polyester ('Terylene'), polyamide under various trade names, and 'Kuralon'. They found that 'Terylene' had less resistance to abrasion, particularly where sharks abounded as they damaged the nets much more than was the case with polyamide. They had also tried monofilament nets from Germany but they found that crabs cut the monofilament so that it was not economical.

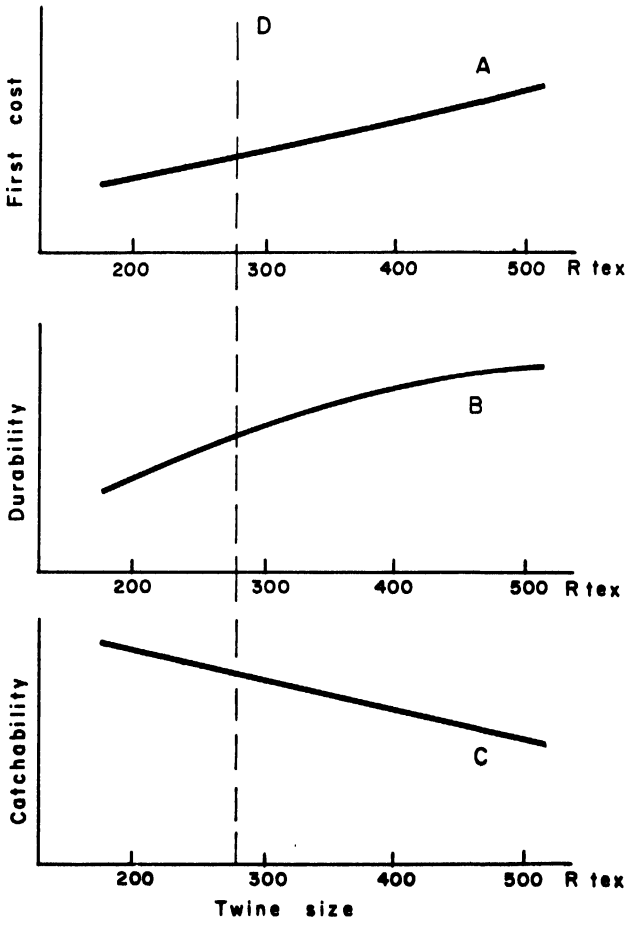
Mr. T. Paramanantharajah (Ceylon): After expressing gratitude to FAO and its fishery officials for the assistance given in developing their fisheries techniques by designing new boats to reach distant grounds and introducing suitable gear, asked that FAO should provide a glossary of technical terms which would enable them to keep abreast of developments and commercial usage. Their development had reached a stage where they were looking forward to the possible use of small sterntrawlers and longlining techniques to work more distant grounds, and he asked that businessmen abroad should remember that there was the opportunity in Ceylon for much development.

Mr. Lowell Wakefield (U.S.A.): Our experience is that trawling is actually the most efficient way of catching king crabs, but having regard to overall efficiency, the quality of the output and the need for conservation, other methods of catching are used such as the entangling net and the crab pot. Japan used the tangling nets and the Americans used the pots. On the question of selectivity and the possibility of releasing female crabs and immature crabs he thought the pots were superior. He mentioned that the formerly used standard crabpot had been displaced in the last three years by the newly designed large pot, invented by a man who came in from the salmon gillnet fishery and knew nothing about catching crabs at that time. This showed how new ideas came in from new sources.

Mr. H. Kristjonsson (FAO): Gillnetting has proved most effective in tropical areas and in Ceylon 20 to 30 thousand gillnets were now being used since their introduction by FAO. It was, however, also a quantity fishery in developed countries. For instance, Iceland was an example where it had large-scale application.

Fishing had become too complex and too highly capitalised to rely on flair to the same extent as in the past for the selection of the gear, methods and materials. By techno-economic studies we must evaluate more exactly the costs and earning factors, and select the most economic tools. Taking the Icelandic cod fishery with gillnets as an example, each boat fishes about 100 nets per day. These nets last sometimes only a few weeks and each boat consumes 300 to 400 nets in a four-month season. For each net the netting alone costs about £7 to £8 sterling. In its lifetime of, say, a month and a half, each net will catch on the average 1½ to 2 tons of fish worth £40 to £50 sterling. Thus the netting alone (the framing lines, floats and stones are used again) costs 20 per cent of the value of the catch taken in that net as long as it lasts. This is an appreciable cost factor, and much stands to be gained if you can shave a little off it, or if you can increase the value of catch by selecting a more efficient net.

The first cost of the netting varies with the diameter of the twine, somewhat like curve A in the Figure below. The durability is haphazard in Iceland owing to bad weather and heavy fishing, but in other countries where the climate is more



clement durability would vary with twine size, something like curve B.

Catchability of fine nets is normally much better than that of the heavy nets, so the catchability might vary like curve C. Now our problem is to determine line D, i.e., the optimum twine size. It will vary from country to country, from fishery to fishery, but can be calculated wherever the fishery is on a big enough scale to give statistically valid numbers. This brief statement serves only to provoke thought on this matter both among the economists and the gear technologists who will have to collaborate, since the economic considerations are inevitably limited by technical factors as is so often the case in engineering.

Dr. Miyazaki (Japan): One of the features of the I-type net hauler described in the paper on drift net haulers is that the head section is interchangeable with another for tuna long-line work. The SU-type, by fitting another head section on its base, has a special groove arrangement different from that of the YM-type. In the SU-type the two wheels of the drum are each fitted on a different shaft, the inner wheel at a right angle, while the outer wheel is a little off the right angle with the horizontal axis of the drum. But the way the drum takes hold of the net and releases it down is essentially the same as with the YM-type.

Mr. C. E. P. Watson (U.K.): In Kenya they had not found monofilaments to give any great superiority over any other materials and the majority of nets continued to be made of ordinary white nylon. Following earlier reports regarding the great superiority of certain Japanese coloured nets, they had tested as many different colours as they could and had not found any advantage in Japanese salmon pink. Tests made in Lake Victoria in both clear and dirty water, showed that colour made no difference whatsoever to the catching power of different nets. Much the same experience was obtained with monofilaments. The most important factors to determine the relative economy of gillnets were the strength of the material and its resistance to deterioration. One big disadvantage of monofilament net was its tendency towards permanent distortion of the mesh bars after fish were caught. This increased even more the tendency of the monofilament nets to be very bulky in stowage with the result that canoes could carry fewer nets than otherwise would be the case. In trap fishing they had replaced the traditional form of stationary traps called pata and ozea traps made of fence sections of woven coconut fibre, with an identical form of trap using polyethylene net in place of the coconut fibre. This, tested alongside the traditional trap, had showed a great increase in catching power with the result that many had been sold and were showing good commercial results.

Recent Developments in Icelandic Herring Purse Seining

Abstract
Since 1958 the annual yield of the Icelandic herring fishery has increased rapidly after 14 very lean years. Apart from natural causes, such as fluctuation in stock strength, this increased catch is partially attributable to the very drastic changes in Icelandic herring fishing techniques, particularly to organized fish searching with asdic and a new technique in asdic-guided purse seining for deep-swimming schools, mechanized handling of the nets by power blocks, and the use of deeper and stronger seines of nylon netting hung to Terylene ropes. The author describes the technological developments in the Icelandic purse seine fishery over the last two decades, from the two-dory system with carrier boat, through an intermediary stage when the net was operated from a single dory towed by the carrier vessel, to the present system whereby the net is operated from the main boat, usually stacked at the stern after the wheelhouse on vessels up to 85 ft, or on the boat deck on larger vessels. The asdic fish searching is discussed and a detailed description given of the tactics of encircling submerged schools by careful asdic plotting, taking full account of the interaction of wind, current and swimming direction of the school. Normally the boat starts shooting into the wind. The purse line gallows are placed far up forward. Although a power skiff is not normally needed, most boats carry one for use in adverse conditions to either tow the boat out of the net or the net away from the boat. Catches of 100 or even 200 metric tons do not present serious difficulties. Using nets 200 to 240 fathoms long floatline and 60 to 70 fathoms deep, stretched, at the centre but tapered sharply at the bunt end, several top boats (90 to 110 ft) have an annual average catch of 6,000 to 8,000 tons each. This method has made possible year-round herring purse seining in Iceland, which previously was limited to three summer months off the North Coast for surface schooling herring. This has contributed to bolstering the Icelandic herring catch to a record 478,000 tons in 1962.

Recent Developpement des operations a la senne coulissante en Islande

Resume
Depuis 1958, la production annuelle de la pêche au hareng, en Islande, s'est accrue rapidement après 14 années de maigre production. En dehors des causes naturelles telles que les fluctuations du stock, cet accroissement est attribué partiellement au changement radical de la technique islandaise de pêche au hareng et plus particulièrement au nouveau système de localisation du poisson au moyen de l'asdic, à une nouvelle technique de détection des bancs profonds, toujours au moyen de l'asdic, à la manipulation mécanique des filets par des power-blocks et à l'utilisation de filets plus profonds et plus forts, assemblés sur des ralingues de térylène. L'auteur décrit les développements technologiques dans la pêche islandaise à la senne traînante, pendant les deux dernières décades, du système à deux canots avec bateau-porteur, en passant par un stade intermédiaire où le filet était opéré par un seul canot tiré par le bateau-porteur jusqu'au présent système dans lequel le filet est opéré par le senneur lui-même, le filet étant rangé à l'arrière du bateau derrière la timonerie sur des bateaux de 26 m ou sur le pont à canots sur les grands bateaux. La communication traite de la localisation du poisson à l'ascid et donne une description détaillée des tactiques utilisées pour encercler les bancs de harengs submergés, à partir des indications fournies par l'asdic, en tenant compte du vent, du courant et du déplacement du banc. Normalement le bateau commence la mise à l'eau du filet, dans le vent. Les potences pour la ligne coulissante sont placées à l'avant. Bien que le canot motorisé ne soit pas toujours utilisé, la majorité des bateaux en emporte un pour touer le bateau hors du filet on pour éloigner le filet du bateau selon la direction du vent. Des captures de 100 jusqu'à 200 t ne présentent pas de sérieuses difficultés. Des bateaux de 27,5 m à 33,5 m, utilisant des filets de 370 à 440 m de ligne de flotte et de 110 à 130 m de profondeur, étirés au centre mais effilés au sac, ont obtenu une capture annuelle d'environ 6.000 à 8.000 t. Grâce à cette méthode, il est maintenant possible de pêcher le hareng, en Islande, toute l'année alors qu'auparavant cette pêche était limitée à trois mois pendant l'été, sur la Cote Nord et à des bancs de surface. Ceci a contribué à porter la capture de 1962 à un poids record by 478.000 t.

by
Jakob Jakobsson
Reykjavik

Adelantos recientes en la pesca del arenque con redes de cerco en Islandia

Extracto
A partir de 1958 y tras 14 años de escasez, la captura anual de arenque en Islandia ha aumentado rápidamente. Excluídas las causas naturales, como fluctuación de las poblaciones, el incremento se puede atribuir en parte a cambios radicales de las técnicas de la captura, particularmente la búsqueda organizada con asdic y un nuevo sistema de pesca al cerco di cardúmenes profundos guiado por asdic, empleo de motones mecánicos en la maniobra de la red y uso de paños de nylon más altos y robustos con relingas de terilene. El autor describe los adelantos técnicos de la pesca al cerco en Islandia en las dos décadas pasadas, desde los días de los dos "dories" con una embarcación de transporte, a través de la fase intermedia en que la red la calaba un solo "dory" remolcado por el transportador, al sistema actual en el que el arte lo manipula la embarcación principal y normalmente lo estiba a popa, detrás de la caseta del timón, en barcos hasta de 85 pies o en la cubierta de botes en los de mayor eslora. Examina el autor la localización de peces con el asdic y da detalles completos de la manera de cercar cardúmenes sumergidos siguiéndolos con el asdic y teniendo en cuenta el efecto del viento, de la corriente y la dirección en que se mueven los peces. Normalmente el calamento comienza con el barco proa al viento. Los pescantes de la jareta están muy a proa. Aunque por lo general no se necesita un bote do motor auxiliar, casi todos los barcos lo llevan para sacar a remolque el barco fuera de la red o separar ésta de aquél so las condiciones son adversas. Capturas de 100 y hasta de 200 tons no presentan dificultades graves. Con redes de 200 a 240 brazas en la relinga de corchos, 60 ó 70 brazas—estiradas—en el centro, pero reduciéndose considerablemente hacia el copo, varias embarcaciones muy pescadoras, de 90 a 110 pies de eslora, han logrado capturas anuales de 6.000 a 8.000 tons cada una. Este método ha hecho factible pescar al cerco arenque en Islandia durante todo el año, en tanto que anteriormente sólo se pescaba el que se agrupaba en la superficie en los tres meses del verano en la costa norte. De esta manera la pesca al arenque en Islandia en 1962 alcanzó la cantidad sin precedente de 478.000 tons.

DURING the last few years the annual yield of the Icelandic herring fishery has increased rapidly after 14 years of very low yield, 1945-1958. Generally such large fluctuations are at least partly related to natural causes. While the greatly increased herring catch in Iceland seems no exception to this, the past few years have seen very drastic changes in port fishing technique which have contributed greatly to the increased yield.

This paper will describe and discuss these technical changes and the resulting changes in fleet fishing power with regard to fish finding, fishing tactics, gear handling and gear changes. To assist understanding of these revolutionary changes, a brief historical and general sketch of the fishery follows.

Historical and general sketch

The history of the Icelandic herring fishery has been described by Thórdarson (1930) and clearly outlined by Fridriksson (1944). Only a few points of technical interest will be mentioned here.

During the first four decades of purse seine herring fishing (1904-1944) the Icelandic fishery was a typical inshore and near-water one. The main fishing grounds remained within or just outside the north coast bays and fiords throughout this period. The traditional American two-dory purse seine system suited these conditions very well and proved most successful. Herring were located most frequently by sight since hand sounding equipment used in the Norwegian winter fishery could be used only infrequently, owing to special characteristics in the schooling behaviour of the north coast summer herring.

Until the forties the 30 ft-long dories were propelled by oars and shooting, pursing and hauling were manual. During the late forties small diesel or petrol engines were installed in the dories, saving the crew some labour.

Nets were of cotton and measured approximately 120 to 180 × 30 fathoms with a centre bag and wings on either side.

Fishing boat sizes varied greatly; from 45-ft wooden craft to 140-ft steam trawlers with a crew of 16 to over 20 men. Smaller boats towed their dories. Larger vessels (above 70 ft) carried the dories in large davits. Clearly this method is mainly suited for fishing in sheltered waters since it makes the boats much more vulnerable in heavy seas when steaming. Lowering and lifting the dories can also be quite hazardous in the open sea.

The migration and behaviour pattern of the north coast herring changed drastically after 1944. The herring no longer entered the fiords and seldom were good schools found in the near waters. The fishery collapsed. The annual yield of the purse seine fishery fell from the level of 150,000-200,000 tons in 1944 to 10,000-40,000 tons in 1945-1958 (Jakobson 1963).

Low catches forced a change from the two-dory 18-man system to a one-boat system needing only 10 to 11 men. Differences include:

(a) The bag is at one end of the net with only one wing.

(b) When shooting, the dory is towed alongside the vessel, which then makes a whole circle, instead of the two dories each making a semicircle.

(c) Shooting depends on power from the ship's main engine instead of the less dependable dory engines.

(d) Pursing is performed on board the main vessel and the purse line is hauled by using the ship's trawl or deck winch. The net itself was hauled manually from one end only. This was often heavy work caused by the faster drift of the larger vessel.

The main advantage of this one-dory system, apart from reduction in manpower, was that, once the dory had been tied alongside the vessel, the shooting of the net needed no extra preparation such as lowering the dories from the main vessel, starting dory engines and sailing the dories toward the school. This difference often proved valuable in keen competition. Most of the Icelandic fleet changed to this one-dory system from 1946 to 1960. The changeover enabled experimentation with asdic-guided shooting, described in Section 4 of this paper.

Location of herring in Icelandic waters

Herring detection in the north coast purse seine fishery from 1904 to 1953, depended almost entirely on visually sighting surfacing schools. As a result, aerial scouting began as early as 1928 and is still used. While herring entered the coastal waters their surfacing was sufficiently regular to show the great merit of aerial scouting, i.e. the large area that can be covered per unit time in good flying weather. But if schools stay far off shore, surfacing occurs much less frequently and more irregularly (Jakobsson 1961) and aerial scouting becomes less dependable.

Contrary to many other fisheries, the introduction of vertical echo sounding did not cause any great changes in the location techniques in the Icelandic north coast fishery. Schools were occasionally spotted on the echo sounder while cruising, but usually it proved very difficult to relocate them, owing to their very limited vertical spread (Jakobsson 1959).

It was not until horizontal echo ranging equipment (asdic), installed in a Norwegian research ship, was used on Icelandic grounds in the early fifties by Finn Devold and his technical staff that acoustic devices proved successful for locating herring in this area (Devold 1951). Asdic was installed in the Icelandic inspection and research vessel *Aegir* in 1953. Since then horizontal acoustic ranging has played an increasingly large part in locating herring concentrations off Iceland's north and east coasts. From 1953 to 1958, the main value of such surveys was to locate *probable* fishing grounds. Actual fishing did not generally start until the schools surfaced. Information on these probable areas became valuable for subsequent aerial scouting.

Asdic units were first installed in Icelandic fishing boats in 1954 and since then more and more Icelandic fishermen have learned to shoot purse seines round submerged schools. After 1958 this method became fairly widespread. During the last four years the value of asdic surveys has greatly increased, since concentrations of good schools, submerged or not, can now be fished by the new methods. Figs 1, 2 and 3 show a few examples of concentrations of herring schools located by the research vessel *Aegir* that proved very profitable for the fishing fleet. During the summer of 1962, three Icelandic ships, under the leadership of the scientist in charge on board the *Aegir*, continually searched the

whole fishing area, tracked down herring concentrations, followed the migrations and reported on schooling behaviour, etc. The value of thus dividing fish location and actual fishing may be difficult to determine, but all fishermen agreed that over 50 per cent of the 1962 herring catch stemmed directly from the three survey vessels' work.

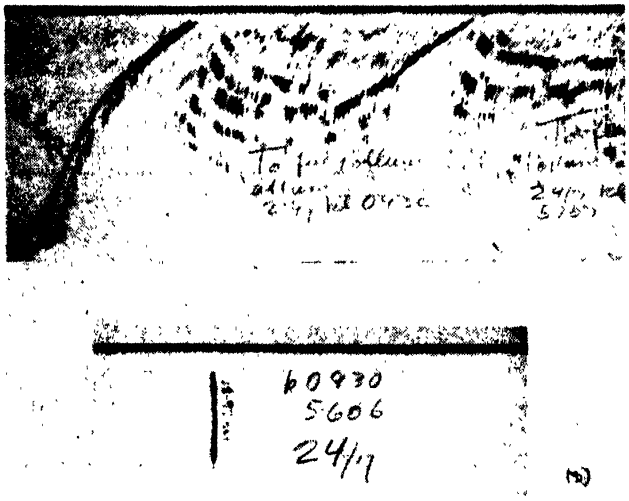


Fig 1. Recordings from the K.H. whalefinder asdic (upper fig) on board the Aegir and the Simrad Echo Sounders (lower fig). Range 0 to 2,000 yards. Two schools are contacted at the maximum range and one is picked up on the echo sounder, the vertical echo being from 18 to 22 m. While waiting stationary until the fishing fleet comes, schools are contacted in all directions (see asdic (upper) echogram).

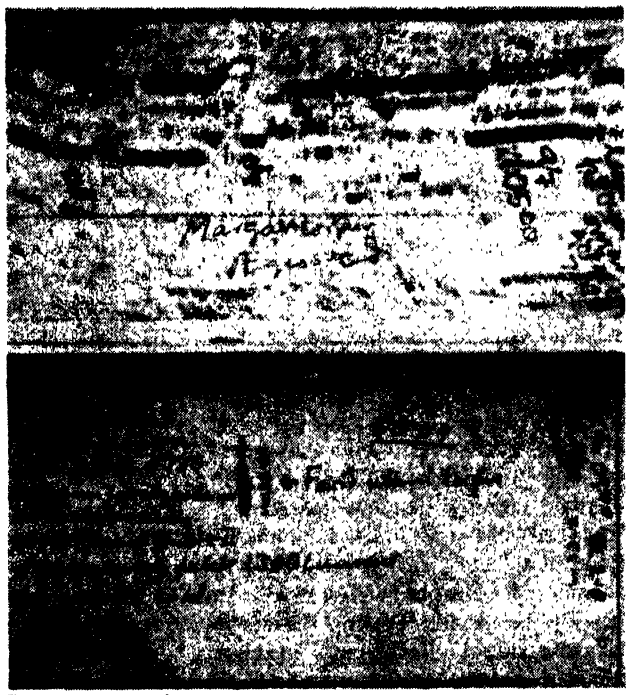


Fig 2. See explanation to Fig 1. Herring concentrations were located on the asdic at approximately 0500 hours, as shown on the echogram, and one of the schools is as usual picked up on the echo sounder that shows the vertical echo trace to be from 30 to 88 m. The fleet arrived between 0730 and 0800 hours when the schools had started to descend due to their diurnal vertical migrations. Yet the Vidir II reported at 0800 a shot of 130 tons fine quality herring from the school shown on the lower echogram.

Fig 3. See explanations of Fig 1. Late summer echoes in areas of considerable thermocline, showing how only faint echoes are received in the longer range due to the fact that in the distance of 700 to 2,000 yards most of the beam passes underneath the schools. This area of herring concentrations yielded about 20 thousand tons in the following two to three days.

If these three vessels had been engaged in actual fishing, one could reasonably expect that their share in the catch would be proportional to the average catches, i.e. the increase in the total yield would have been only of the order of 1 to 2 per cent instead of about 50 per cent. The success of these search vessels results partly from their using, as far as possible, all previous environmental research results. The rapidly increasing knowledge of the herring's relation to various environmental factors is thus used and tested in daily work during the season. This has resulted in many tentative scientific suggestions being strengthened or discarded.

As a result of a close correlation between dense herring concentrations and sharp temperature gradients, many fishing boats are equipped with thermometers. Before the 1963 season a few boats will install continual registration type thermometers.

Some other factors in herring detection are various navigational aids, such as radar, semi-automatic radio direction finders, and radio communication. The latter is of great value since information regarding concentrations located by individual boats is immediately passed by radio to the research or search vessels, which forward such information along with their own findings, to the fleet.

Vestnes (1962 and earlier mimeographed paper), has proposed an organized searching method in which a number of fishing boats at short distances abreast, would cruise parallel courses, thus thoroughly searching a large area in a short time. The Icelandic fleet has tried this on a few occasions, especially during the new winter herring fishery off the south west coast, where long spells of fierce gales prevent search boats from keeping continuous contact with the herring concentrations. On these occasions when the weather becomes better the research vessel usually cruises along one of the edges of an area of probable concentration (as judged by hydrographic conditions) and the fishing boats then voluntarily arrange themselves at intervals of one-half to one mile. Thus 50 to 80 boats have covered the whole probable area in a few hours and invariably positive

results have been obtained. Regarding the method of the actual searching technique, both Vestnes (1962) and Júlíusson (1961) have described in detail how the asdic beam can be best utilized, e.g. by searching in steps from 75° on one side toward the course line and then going quickly to the other side and searching forward again, always allowing enough time between steps for an echo to be received. All manufacturers of echo ranging equipment supply detailed information on this point.

Use of asdic for netting submerged schools

Small horizontal transducers were first installed in Icelandic herring boats in 1954-55. They were connected with ordinary echo sounders normally used for vertical sounding. Their very limited range could not locate new herring areas. However, in an area of rich concentrations, schools were frequently located and experiments in shooting the purse seine net around such schools began as early as 1954. Captain Eggert Gíslason of the *Vioir II*, after innumerable failures, obtained the first positive results. Since then this method of shooting by asdic alone has become more and more widespread, and it can be stated without any reservation that only those captains that have gained experience and skill in using this method have been successful during the last five years. Those who insist on shooting only when the schools surface, or, passing over the schools, trying to use vertical sounding, have not proved competent in this highly skilled fishery.

Thorsteinn Gíslason (1961) and Juliusson (1963) have described this method to some extent but operations will be outlined here in somewhat more detail and from a slightly different angle.

In principle the method is quite simple, since the net is simply to form a circle with the middle of a school centred. Assuming the school is circular, the net and the edges of the school should form two concentric circles. The distance between these concentric circles is the difference between their radii, i.e. $\frac{L}{2\pi} - \frac{D}{2}$, where L

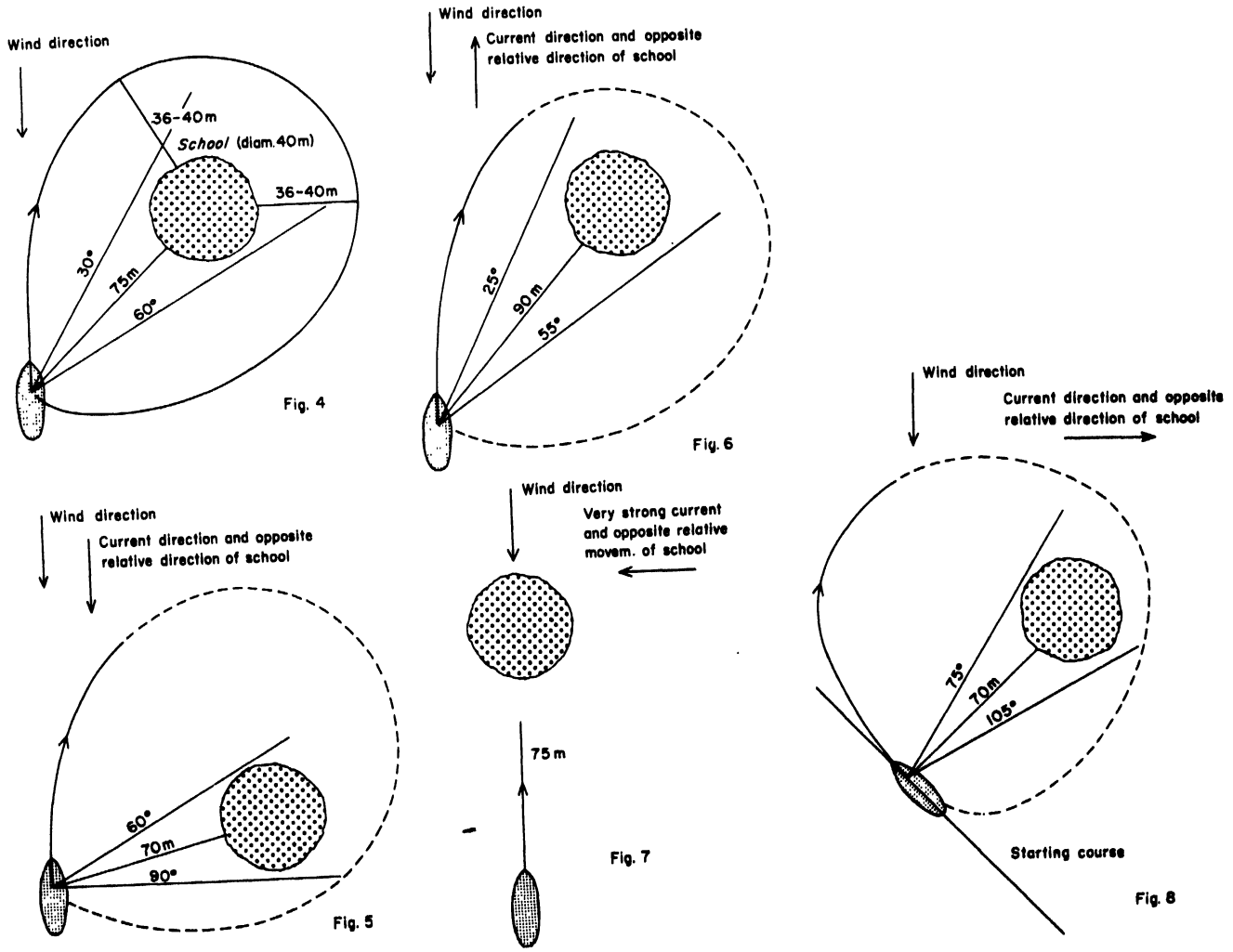


Fig 4. Starting position and the subsequent course of asdic-guided shooting. The dimensions refer to a 90 to 100 ft boat, 400 m long purse seine net and a school of 40 m diameter.

Fig 5, 6, 7, 8. Starting positions under varying conditions of current and relative movements of schools. The dimensions are the same as in Fig 4, and in all cases the school is expected to be in the position shown in Fig 4 when the circle has been completed.

is the length of the net and D is the diameter of the school, both of which are known. If this worked strictly in practice the method would be to get the school 90° to starboard in the distance $\frac{L}{2\pi} - \frac{1}{2}D$ and then manoeuvre the ship through this distance with the school always 90° to starboard until the ring was closed. Suppose the net were 400 m long and the school 40 m in diameter, the distance of the boat from the school while shooting should be

$$\frac{400}{2\pi} - 20 = 45 \text{ m.}$$

Owing to various reasons, maximum results are not obtained by shooting strictly by this formula. The bag end of the net is, for instance, not as deep as the rest of the net, and as a result the purse seine will not prevent the escape of a school in that area as efficiently as elsewhere. Then it is clear that during the pursing operation the last opening to be closed is where the ends meet, i.e. at the boat. It has therefore proved advantageous to shoot not in an exact circle, but more in an ellipsoid manner, making the edge of the "ring" egg-shaped and starting and finishing shooting at the "pointed" section. This infers that in the example above, instead of starting to shoot approximately 45 m from the school (or 64 m from its centre) and keeping that distance constant throughout the operation, one starts at a greater distance with the centre of the school considerably less than 90° to starboard. Still using 400-m net it has been found best to have the centre of the school approximately 45 to 50° on the starboard and the distance about 75 to 85 m. At that distance a school of 40 m diameter will give echoes of more than 20° width and should disappear in just over 30° from the starting course. Then the net is shot in only a very slight curve until the school is approaching 90° to starboard, and then it should be at a distance of not more than 40, or less than 60 m, from its centre. Assuming no significant current or movement of the school, this distance is kept as constant as possible until the boat has made the turn and is heading for the buoy again, i.e. the bunt end (see Fig 4).

Experience has shown that in most cases it is advantageous to start shooting with the wind straight ahead. Then the boat is also in that position while pursing takes place and in bad weather this is the best position for manoeuvring. As the net is hauled, the boat slowly makes almost a whole circle, finishing with the stern or even the port side, into the wind when brailing starts. It should be noted that those boats that are heavy on the rudder (longer than 100 ft) start with the wind 10 to 15° on the starboard side.

Figs 5 and 6 show schematically how the starting position changes when the ship is heading into and going with the current, respectively. These figures explain equally well the case of no current and the school swimming up or downwind. In fact, the two cases appear identical on the asdic, i.e. Fig 5 thus shows the starting position when the school moves away from the stationary ship, whereas Fig 7 shows the starting position when the school approaches a stationary ship that in both cases is heading into the wind. Shooting in calm weather, but in areas of strong currents, can be very tricky. If one starts shooting with a following current (school approaching on the asdic) there is a good chance that the school will dive through the opening that inevitably is formed under the ship. This opening cannot be closed until pursing is completed.

This method of shooting has the advantage that the net stays clear of the ship during hauling. There is therefore no danger of it becoming entangled on the ship. When starting shooting in calm weather against the current, the conditions are reversed. Then there is a much better chance of catching the school, but at the same time the net then tends to drift onto the ship and a big loop may be formed on the port side of the ship during pursing and hauling. When the net has been shot in this way, great hauling speed is essential to avoid entangling with the ship. In very strong head current (Fig 5), cases are known where shooting has been successful only if the school is already more than 90° to starboard when the operation begins. Similarly, if there is a strong side current going at almost right angles from right to left when facing the wind direction, successful shooting can sometimes be accomplished only if shooting starts with the school almost straight ahead (into the wind) or even slightly to port (Fig 7).

During six years of practice the most skilled Icelandic fishermen have accomplished successful shooting in a variety of adverse conditions without needing any extra powered skiff or help from other vessels. This is largely due to a complete understanding of the interaction of wind and current on both the ship and net. Another important feature of the method, i.e. the position of the hauling gear, is discussed later.

This discussion shows hows how important it is when shooting by asdic on submerged invisible schools that the captain be absolutely sure of the relative movements of the current, the school and the drift of the boat. The best method is perhaps when approaching the school (at, for example 150 to 250 m) to go at a dead slow speed, or even stop with the school slightly to starboard and heading into the wind. At such a distance the relative movements of the boat and school can be detected; yet there is enough space to manoeuvre into the best starting position. Table I shows in the first column some features that the captain is likely to be able to determine. The second column shows starting positions as shown in Figs 4-8 that are likely to give the best results.

In order to determine the movement of the school some captains prefer, however, to approach from the wind direction and pass it at close quarters before turning into the wind and manoeuvring into a starting position.

Once the shooting position has been chosen the boat must be manoeuvred into it. To determine the exact bearing of the centre of the school at the small ranges just prior to shooting, it has been found most advantageous to trail the edges of the school very carefully and take the centre as the average of the two bearings (see Figs 9 and 10). The captain must then determine

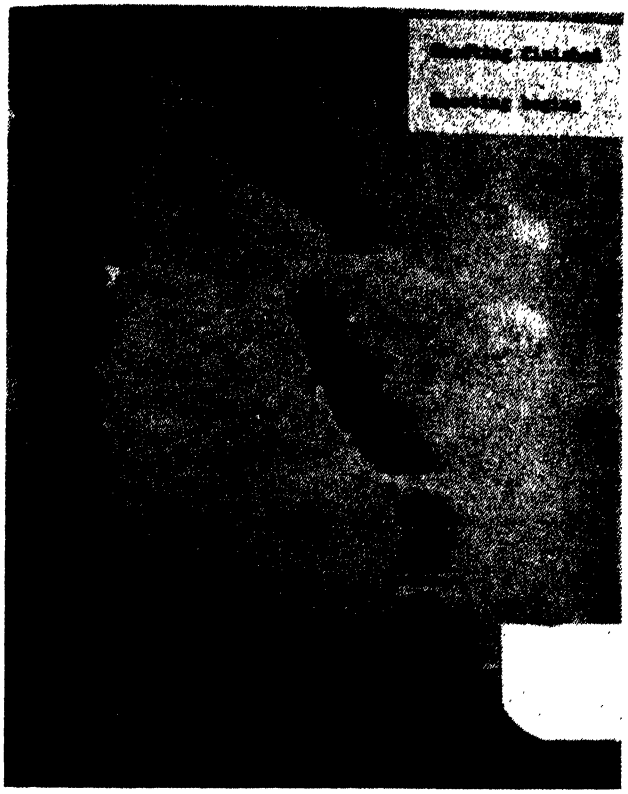


Fig 9. An echogram from M.V. Gudrun Thorkelsdóttir, *92 ft' skipper Thorsteinn Gislason. A school is picked up on the 0 to 200 m scale using horizontal transducer connected with a Simrad echo-sounder. The ship approaches slowly while the skipper is training the beam at the outer edges (2) and the centre (3) of the school, thus finding its exact position as well as its relative movement to the ship. In position 4 the shooting of the purse seine starts, and as the starboard turn is made, the echo of the ship's wake (5) appears. Result: 40 tons of herring. See reference in text.*

whether the school stands high enough in the sea for his particular net. This is done by previously relating the distance at which the echoes of the school disappear from a given horizontal beam. Optimum results of searching by acoustic ranging is usually obtained with the beam narrow and almost horizontal. Since this beam tends to pass over schools at close ranges (Fig 10), most of the Icelandic purse seine boats are equipped with a transducer that transmits another beam at 10 to 25° angle to the ordinary search beam. This slanting beam is mainly used at very close ranges and especially during the shooting operation. Before gaining experience, many fishermen circled the school before shooting. They discovered that the wake acted as an airbubble curtain that blocked all echoes from the school. As a result, some fishermen had only their own ship's wake as a target during the first shot or two.

An experienced captain, Mr. Th. Gíslason, has compared (Gíslason 1961) shooting by asdic with learning to ride a bicycle. As skill increases with practice, soon the balance is so secure that one finds it difficult to imagine ever shooting a purse seine without the aid of asdic. In fact, many Icelandic fishermen today would rather set purse seines around submerged schools than around surfacing ones.

Power blocks and new deck arrangements

Schmidt (1959) described how the Puretic power block was introduced in the American Pacific purse seine fisheries in 1954 and 1955. During the winter of 1956 an Icelandic herring captain, Mr. Ingvar Pálmason, went to the Pacific coast to study this instrument in action. His report (Pálmason 1956) launched experimentation with the Puretic power block in the Icelandic herring fishery in 1957.

All Pálmason's experiments (1957) showed that the Puretic power block was well suited for hauling the Icelandic type of purse seine nets previously used in the one dory system, but the deck arrangement of the particular boat used did not prove convenient. This boat was of the conventional type with the wheelhouse very far aft and there was not enough space for the bulky net on the stern. Hence it had to be hauled midships and most of the deck space was thus occupied by the net. It was not until the summer of 1959 that a real success was made in this respect. Then the captain of the 95 ft vessel *Guðmundur Thórdarson*, Mr. Haraldur Ágústsson, carried out successful experiments by shooting and

Fig 10. Echo picked up on a Simrad herring asdic at a distance of approximately 1,300 m. At a distance of 200 m, the skipper switches over to the shooting scale and starts shooting at the solid black line. The school is at such a depth that only diffuse echoes are received during the operation. Yet the results were 130 tons.

Fig 11. The old "Vidir"—the asdic pioneer—coming to port from one of Mr E. Gislason's successful early experiments with asdic—guided shooting of purse seine. To the extreme left the tow line to the dory can be seen.

hauling the net from the upper boat deck aft of the wheelhouse. Since then this arrangement has been used throughout the Icelandic fleet with the exception of the smaller boats (less than 85 ft) that have no upper deck. Instead, enough space has been provided aft of the wheelhouse and in the starboard passageway leading aft. (Figs 12 and 13).

Fig 12. M.V. Stapafell *at the quay. The powerblock is supported by a davit attached to the wheelhouse and the purse seine is stored on the stern and in the starboard passage. See text.*

Figs 14 and 15 show the power block arrangement of an Icelandic herring boat. On top of the net is a ready buoy (Fig 13). There are two lines shackled to this buoy. One is a rope that is a continuation of the upper edge of the net; the other is the purse line to which a float is shackled (Fig 13). This float is intended to take the

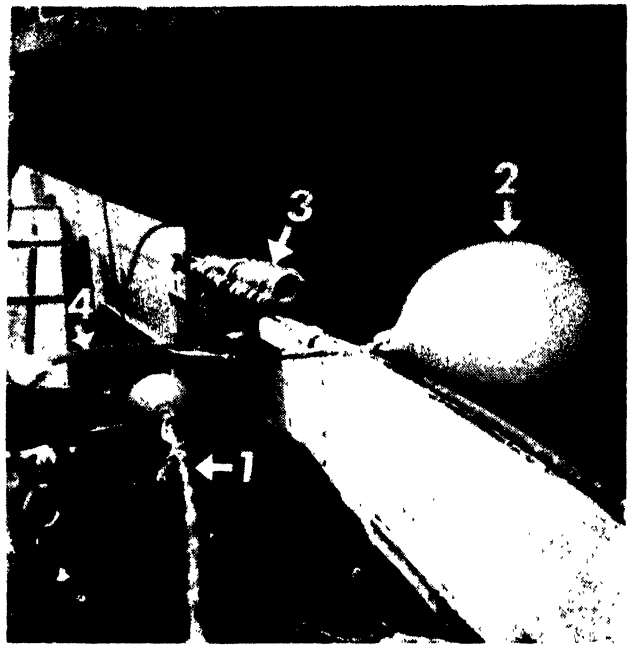


Fig 13. The purse seine net ready for shooting on the stern with the buoy (1) on top as well as a part of the purse line. Note the loop just aft of the purse rings (3) and the large float (2) that is shackled to the loop (4).

Fig 14. Shooting of the purse seine net from the upper deck of F.M. Gudmundur Thórdarson, *the first Icelandic vessel to use the powerblock successfully.*

main weight of the heavy purse line off the buoy to make it easier for the crew to retrieve the buoy when shooting has been completed. Fig 16 also shows how the rings are stored on a metal rod with the purse line running through them. The purse line leads further forward through a gallows block towards the pursing winch that is most frequently situated just aft of the foremast

(Fig 18). The mechanism of shooting, pursing, hauling and brailing is further illustrated in Figs 16-21.

As soon as the end-buoy has been retrieved, the pursing line is unshackled and then reshackled to a short line running through the pursing gallows to the winch (Figs 17 and 18). Usually the whole net is shot, as well as several tens of fathoms of ropes. These ropes are usually

Fig 15. Hauling the purse seine on board F.M. Gudmunder Thórdarson.

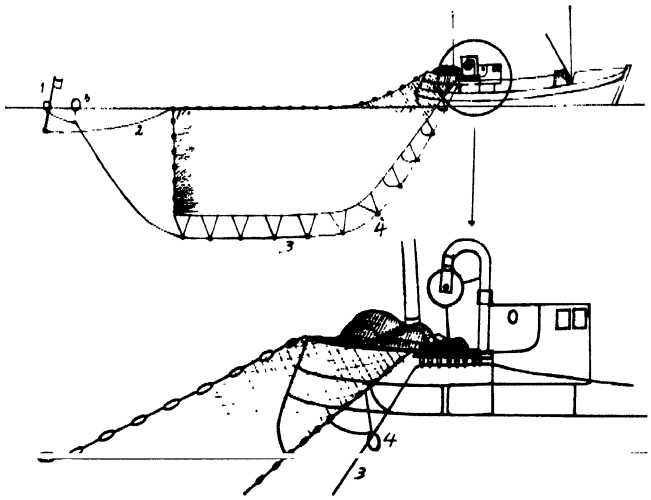


Fig 16. An illustration of the shooting operation showing (1) the buoy. (2) the upper edge rope shackled to the buoy as well as the purse line (3) running through the rings (4) and the net flowing off the upper dory deck.

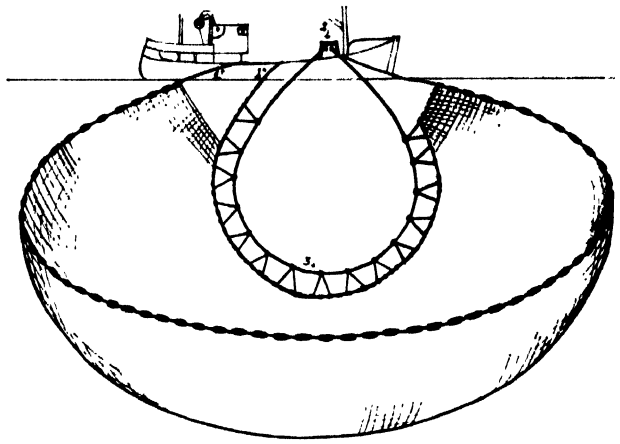


Fig 17. The pursing operations showing (1) the retrieving ropes of the wing and (2) the pursing gallow, and (3) the purse line.

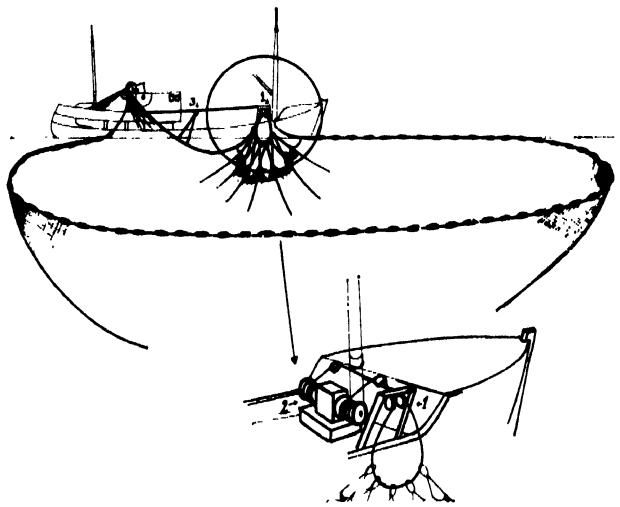


Fig 18. The hauling operation showing (1) the pursing gallow, (2) the pursing winch, and (3) the rings unshackled from the purse line and reshackled on a leading line towards the powerblock.

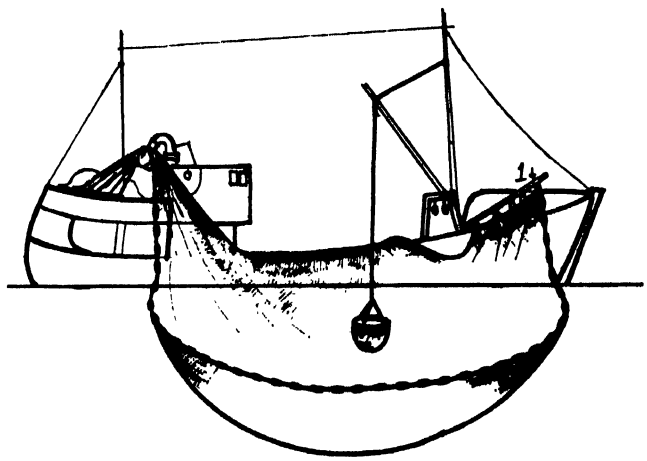


Fig 19A. The brailing operation showing (1) the boom on which the breast is hooked and general arrangement of brailing.

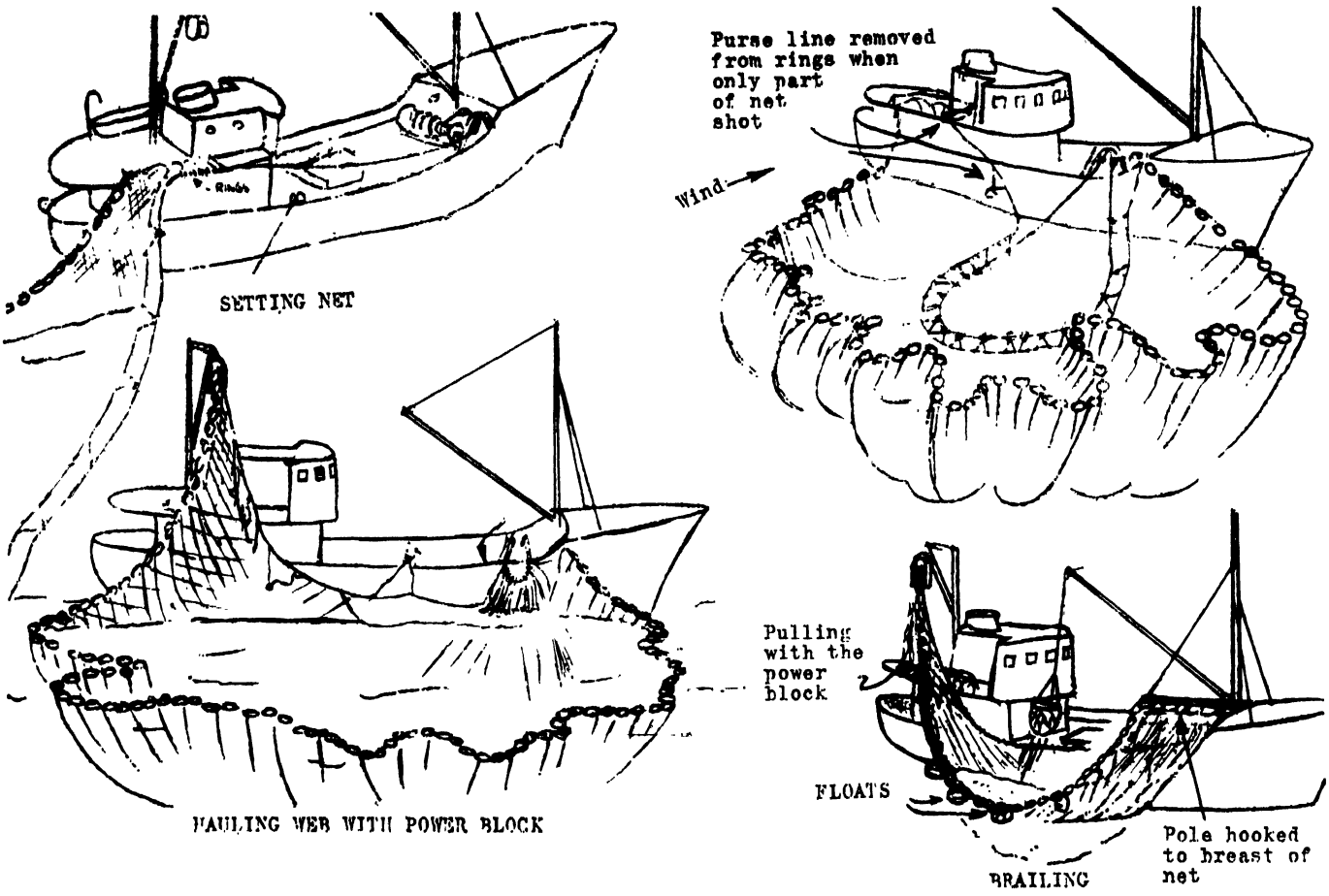


Fig 19B. Further illustrations of the shooting, hauling and brailing operations.

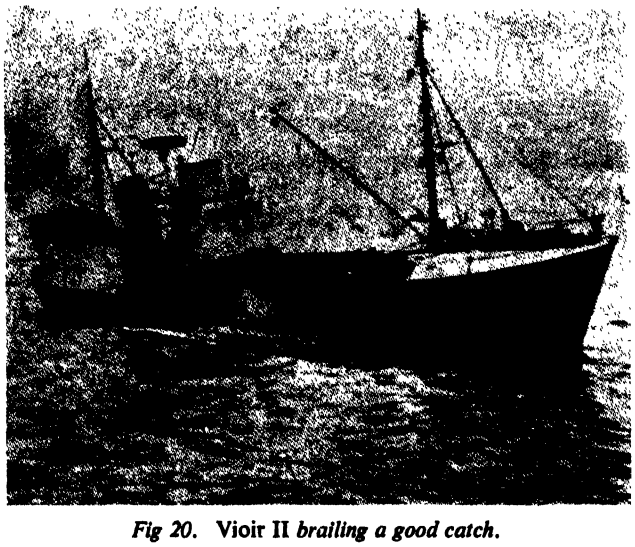


Fig 20. Vioir II *brailing a good catch.*

Fig 21. Brailing is continued as long as the upper edge of the gunwale is not submerged.

hauled during pursing by a special vertical winch (normally used for longlining) on the main deck. When pursing is completed the ropes and the wing end of the net are taken through the power block and the net is hauled continuously until drying-up is sufficient for brailing. When handling large catches it is of great importance that the net be hauled evenly—i.e. both float and leadlines as well as the webbing should come in at the same rate. It is therefore common practice on Icelandic herring boats to lift one edge of the net out of the block and then only haul the other edge and adjacent webbing until the net becomes even again. Although a powered skiff is not normally needed, most boats carry one. In adverse conditions it can tow either the boat out of the purse seine or the net away from the boat, especially if a port side loop is formed in a strong head

current.

The position of the pursing gallows as well as that of the power block is chosen as far forward as possible to avoid fouling the propeller. The power block system has various advantages over the older dory system. Some are: boats can travel faster and in worse weather without the dories; shooting can take place without the delay of lowering dories or skiffs; powered hauling saves crew time and labour; handling of very large catches over 100 or even 200 metric tons, no longer presents serious difficulties or requires extra help from other crews. Finally, the power block has enabled Icelandic fishermen to increase the size (especially the depth) of their nets beyond the effective limit of manual hauling. Successful sets have thus often been accomplished when the top edge of the school is at a depth of 35 to 40 fathoms, using a net 65 to 75 fathoms deep, stretched mesh.

Table I. Boat heading into wind almost stationery, with school at 150 to 200 m distance, bearing slightly to starboard.

Characteristics of radio	Method of shooting	Movement of school	Current
Distance and bearing stable	Shoot by Fig. A	Stationary or moving in same direction as current	No current or in same direction as school
Distance increasing, bearing slightly decreasing	Shoot by Fig. A+1	Moving opposite to wind direction relative to the current	Current with the wind relative to the vessel
Distance decreasing, bearing slightly increasing	Shoot by Fig. A+2	Moving with the wind relative to the current	Current in opposite direction of wind, relative to movement of school
Distance almost constant starboard, bearing increasing	Shoot by Fig. A+3	Moving to starboard relative to the current	Current at right angles to the wind from starboard to port
Distance almost constant starboard, bearing decreasing	Shoot by Fig. A+4	Moving to port relative to the current	Current at right angles to the wind from port to starboard

The net

The Icelandic purse seine nets with the bag in one end have been developing over the last 20 years; first to serve the one-dory system and later for powered hauling without a dory. This second function has only developed since 1958 and the exact shape and trimmings of the Icelandic net have not been stabilized. Each net rigger has his own formulas for details, often according to the captains' special ideas. For illustration the author has chosen two nets from different riggers (Figs 22 and 23).

Both nets have approximately the same over-all dimensions and construction is the same in principle. The main difference is that one rigger uses the same webbing right through the depth of the net, while the other increases the meshsize towards the lower edge. It will be seen that the trimmings are different at the bunt end; one increasing the depth of the net at a higher rate than the other. Both net types have proved very success-

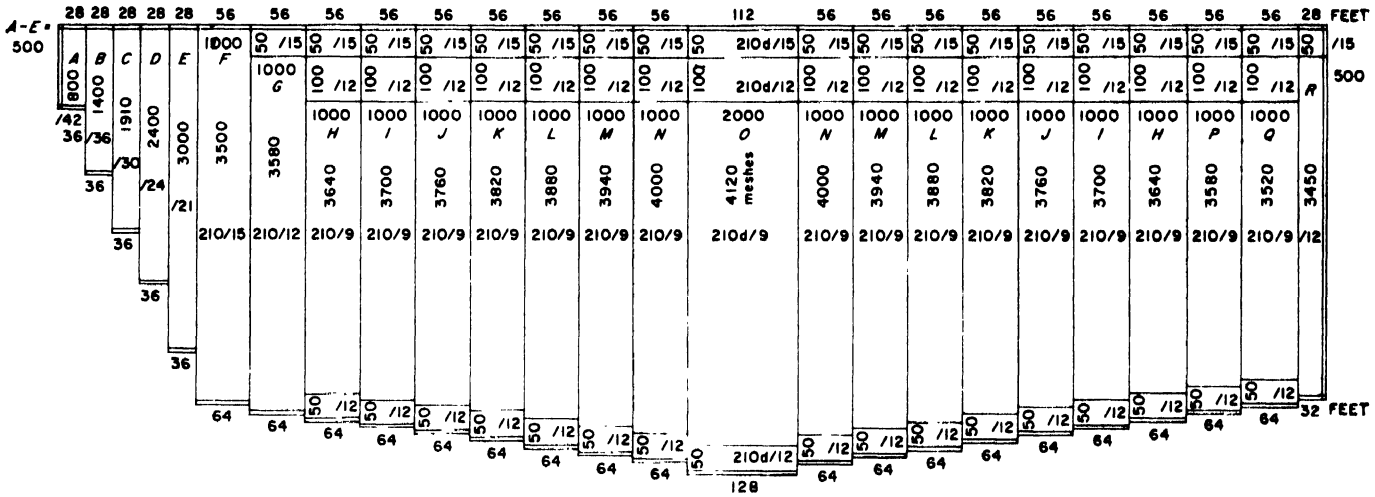


Table II. Specifications of purse seine net shown in Figure 22. (Mesh size equals 40 rows per alen throughout or 15.7 sq. m. Note the Scandinavian term alen equals 24 in.)

Pieces marked	Number of pieces	Twine number	Meshes deep	Meshes long	Length in ft upper edge	Length in ft lower edge
A	1	210d/42	800	500	28	36
B	"	" /36	1400			"
C	"	" /30	1910			
D	"	" /24	2400			
E	"	" /21	3000			
F	"	" /15	3500			
G	"	" /12-15	3580			
H	2	" /9-12-15	3640			
I	"	"	3700			
J	"	"	3760			
K	"	"	3820			
L	"	"	3880			
M	"	"	3940			
N	"	"	4000			
O	1	"	4120	2000	112	128
P	"	"	3580	1000	56	64
Q	"	"	3520	"	"	"
R	"	" /12-15	3450	500	28	36

Fig. 22. This successful Icelandic purse seine net for power hauling was designed by Kristinn O. Karlsson, Hafnarfjördur, Iceland. The length of each panel on the upper and lower edge rope is shown in feet. Throughout the mesh of the net is 15.7 mm bar (40 rows per alen). (Note: the Scandinavian alen = 24 inches.) The lower edge is heavily weighted with lead. In the wing half the weight is 3 kg per ft, but in the bunt half it ranges from 1.5 kg—2.8 kg per ft. Further specifications of this net are shown in Table II. The following selvages are to be included in the total number of meshes: Outermost selvages from A-R, top and bottom and on one side of pieces A and R, are 15 meshes in total with the outermost mesh all around of twine 210d/120 and with suitable decline in strength inwards to produce the best results as regards the strength of the main net in the various pieces concerned. As the drawing indicates there are 50 meshes of twine 210d/15 at the top of all pieces from G-R and 100 meshes from H-Q of twine 210d/12—this is to come in between the main net and the outermost selvage. At the bottom of pieces H-Q there are 50 meshes likewise of twine 210d/12 to be placed between the main net and outermost selvage. All outermost half-meshes throughout the net, top, bottom and sides (i.e. that of twine 210d/120) are 35 mm bar.

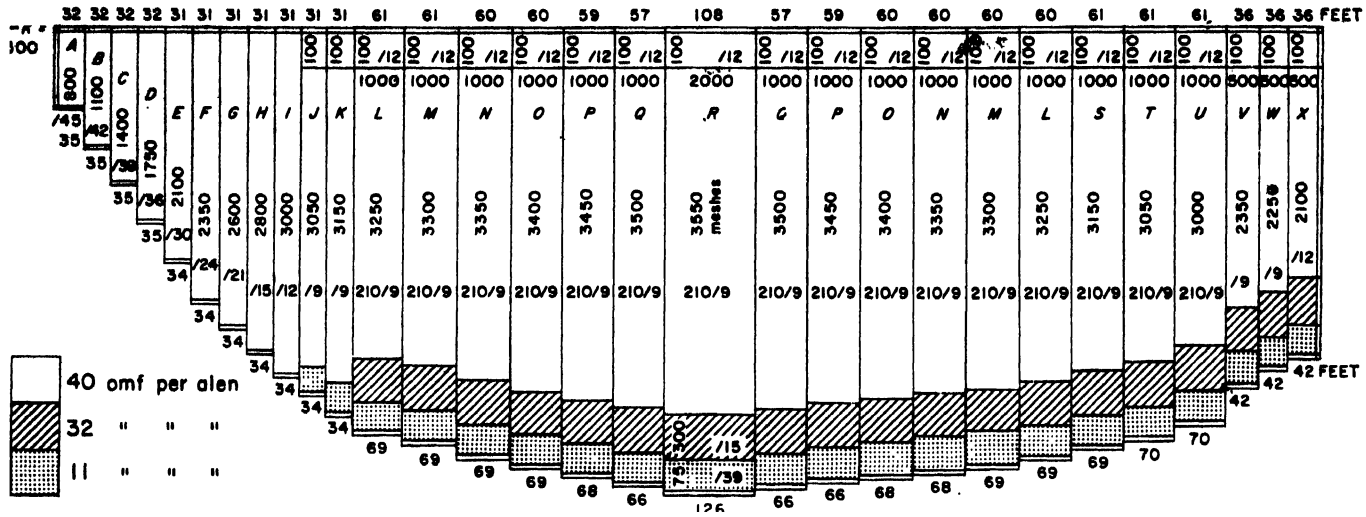


Fig. 23

Table III. Specifications of purse seine net shown in Figure 23. (Mesh size equals 40 rows per alen throughout with the exception of 1 and 2. Note the Scandinavian term alen equals 24 in.)

Pieces marked	Number of pieces	Twine number	Meshes deep	Meshes long	Length in ft upper edge	Length in ft lower edge
A	1	210d/45	800	500	32	35
		" /42	1100	"	"	
		" /39	1400			
		" /36	1750			
		" /30	2100			
		" /24	2350			
		" /21	2600			
		" /15	2800			
		" /9-12[1]	3000			
			3050			
			3150			
		/9-12[2]	3250			
			3300			
			3350			
			3400			
			3450	"	59	68
			3500	"	57	66
			3550	2000	108	126
			3150	1000	61	69
			3050	"	"	70
			3000	"	"	"
		"	2350	500	36	42
		" /12[2]	2250	"	"	"
		"	2100	"	"	"

1) Added 1 piece 300 mesh deep, 32 rows per all (meshsize) of 210d/15 twine
2) Added 2 pieces, one as in 1), the other 75 mesh deep, 11 rows per all of 210d/39 twine

Fig. 23. Another Icelandic purse seine net used for power hauling, as designed by Mr. Johann Klausen, Eskifjördir, denotation as in Fig. 22. Mesh size "40 rows per alen" (the Scandinavian alen=24 inches) with the exception of pieces J-V where two pieces of larger mesh 32 and 11 rows per alen are added at the bottom of the net, each 300 and 75 meshes deep, respectively. Weight same as in Fig. 22. Total length: upper edge 243 fathoms, lower edge 275 fathoms. Selvaging corresponding to that of the net shown in Fig. 22. Depth of centre panel (R) 70 fathoms stretched mesh. See also Table III and text. Note the difference in shape and hanging-in rates of the two nets shown in Figs. 22 and 23.

ful in recent season. Boats using either type were among the top five vessels during the record 1962 summer season. The increased meshsize at the lower edge is expected to make the pursing and closing of the net easier as a result of reduced resistance. The high rate of increasing depth from the bunt end is expected to have the same effect, i.e. easier pursing and better prevention of escape at the bunt end. On the other hand, the lower rate of depth increase (or decrease towards the bunt bag) is said to lessen the danger of large schools causing the net to burst as they are squeezed into the bunt when the body of the net is hauled.

These arguments are not based on controlled experimentation and must be regarded as somewhat speculative. The hanging-in percentage has varied greatly during recent years, but there has been a tendency in the Icelandic type of rigging to hang the nets with less slack. To increase sinking rate, there has also been a very marked increase in the weights on the lower edge. Net specifications show the weight is now approximately 1-1½ lbs. per foot, depending on the purse winch power.

During the last few years of powered hauling, the strength of the framing lines has been increased, and now the floatline assembly consists of three to four lines (each 12 mm diam, Terylene), not counting the line going through the plastic floats. Similarly, the lower edge consists of two to three lines of the same thickness.

For the last three or four years practically all Icelandic nets have been made of nylon twine hung to Terylene lines.

Changes in fishing power in recent years

Changes in the fishing power of various fishing fleets have been estimated by calculating power factors between ships fishing on the same grounds at the same

time (Beverton and Holt 1957). Often it has been possible to correlate the differences in power factors to some measurable features of the ships, such as size or engine power. This has given positive results, especially where the gear is a townet of some kind. It is now the common practice to express the effort statistics of the great trawler fleets in standard units where such power factors are taken into consideration.

For the purse seine fishery it is immediately clear that one of its main features is the importance of fish finding. This may vary greatly from year to year, depending on availability of the fish concentrations. During the early years of Icelandic purse seining there were frequently such large concentrations of herring surfacing in the coastal waters that modern fish finding devices would probably have been of little or no importance. In such circumstances of high availability, herring boats function as cargo vessels and fishing power is closely correlated to the ship size and unloading speed.

Taking the other extreme, e.g. herring fishing out in the ocean off the north coast of Iceland where schools seldom surface, the probable area is very large compared with the area occupied by visible schools. In such circumstances the boat spends almost all the time searching, and differences in searching power would therefore obscure any correlation with other features of the ship.

The increased division of work between searching and catching in the Icelandic fleet and the close radio communication has again decreased the importance of differences in each ship's fish finding power. During the 1962 season, search ships were in contact with workable schools throughout the season, thus greatly decreasing searching time of individual boats.

It has been estimated that at least two-thirds of the total yield of the season was caught by asdic-guided shooting round invisible schools. In this case, fishing power must depend very much on the acoustic ranging instruments and especially the captain's skill in their use. Admittedly this method requires considerable practice and great understanding of wind and current interactions on the ship and net. Thus the "captain effect" is so great that it obscures any relation with the various features of the ship. There have, for instance, been several cases where a change of captain, with no change in instruments or gear has made a particular boat's fishing power rise or fall 10 to 20 times. The calculation of unbiased power factors and the subsequent correlation of these with measurable features of the fishing vessels is thus a very complicated and difficult process. Consider then the very sudden rise of the Icelandic herring yield during the last few years, reaching a record 478,000 metric tons in 1962. Compare this with the well-known decline of corresponding fisheries that are partly based on the same stocks. The comparison shows clearly that fish finding, asdic-guided shooting, powered hauling technique and the resulting increase in the depths of the nets used on the boats in this fishery have brought about enormous changes in the fishing power of the fleet. Apart from that, these techniques and instruments have made it possible to instigate new successful winter and spring seasons off the south coast of Iceland where purse seining is performed under adverse conditions up to windforce 6 and in quite heavy winter swell.

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Sonar Instruction Courses for Fishermen

Abstract
Since World War II the use of acoustical instruments in fisheries has become more and more important and the stage has been reached where purse seiners without modern electronic equipment installed fail to find crews. In the Norwegian fisheries the need for training in sonar operation became an urgent matter some years ago and, at the request of fishermen, suitable instruction courses were organized by the Institute of Marine Research in co-operation with Simonsen Radio A/S, Oslo. The courses given include the theoretical elements of wave propagation and basic electronic functions of ultrasonic equipment, as well as instruction on the location and catching techniques with the use of sonar equipment. The men were thoroughly trained in the three main sonar search patterns. In sonar operation, as soon as contact is made with a concentration of fish, the vessel is aimed direct at the school to a distance of between 40 and 70 m from it. The seine is then shot while the vessel keeps at the same distance from the school, steering round it until fully surrounded. The paper contains definitions for the various types of echoes received on the sonar which generally have a disturbing effect in recognizing the real fish echo traces. The course included practical training in searching and keeping contact with a school of fish and consisted, in the first instance, of locating an artificial target and later on of real fish schools. Eight courses have been given up to the present and much experience has been gained. It would appear that slightly more instruction should be given in fundamental principles but that the training in classification and identification of echo traces has, in general, produced the results envisaged.

Cours d'instruction de Sonar pour les pecheurs

Resume
Depuis la deuxième Guerre Mondiale, l'utilisation des instruments acoustiques dans la pêche est devenu de plus en plus importante à tel point que, maintenant, les senneurs non équipés avec des instruments électroniques modernes ne trouvent plus d'équipage. Depuis quelques années dans les pêches norvégiennes, la nécessité d'un entraînement pour utilisation du sonar devenait urgente et, à la demande des pêcheurs, des cours d'instruction ont été organisés par l'Institut de Recherche Maritime, en coopération avec la "Simonson Radio A/S" Oslo. Les cours donnés comprenaient l'étude des éléments théoriques de la propagation des ondes et les fonctions électroniques de base d'un équiepment ultra-sonique, aussi bien que l'étude des localisations et techniques de pêche a l'aide de l'équipement sonar. Les trois principaux systèmes de balayage ont été inculqués aux élèves. Dans l'opération "sonar", dès que le contact a été établi avec une concentration de poisson, le bateau est dirigé sur le banc jusqu'à une distance de 0 à 70 mètres. La senne est alors mise à l'eau et le bateau, tout en conservant toujours la même distance du banc, tourne autour de celui-ci jusqu'à ce que le banc soit complètement encerclé. La communication comporte des définitions de différents types d'échos reçus par le sonar et sur lesquels il est parfois difficile de reconnaître les traces réelles des poissons. Le cours comprenait aussi un entrainement pratique dans le recherche des bancs et la façon de garder le contact avec ces bancs. Les premières lecons ont été faites sur des cibles artificielles puis plus tard, sur les bancs véritables. Huit cours ont été donnés jusqu'à présent et on en a tiré beaucoup d'expérience. Il semble que l'étude des principes fondamentaux doive être augmentée mais par contre, l'entraînement dans la classification et l'identification des traces d'échos a, en général donné les résultats espérés.

Cursos de capacitacion de pescadores en el empleo de sonar

Extracto
Desde que se acabó la segunda guerra mundial el empleo de instrumentos acústicos en la pesca ha adquirido cada vez más importancia y ha llegado el momento en que los barcos que emplean redes de cerco de jareta y que no están dotados de equipo electrónico no encuentran tripulación. En Noruega, la necesidad de enseñar el funcionamiento del sonar adquirió carácter urgente hace varios años y, a petición de los pescadores, se organizaron cursos de capacitación por el Instituto de Investigaciones Marinas en cooperación con la Simonsen Radio A/S de Oslo. La instrucción dada comprende elementos teóricos de propagación de las sondas, funciones electrónicas fundamentales del equipo ultrasonoro y técnicas de localización y captura con el auxilio de sonar. Los pescadores recibieron una capacitación muy completa en las tres modalidades principales de la búsqueda con sonar. Cuando se emplea este sistema, el barco, tan pronto como se ha establecido contacto con una concentración de peces, se dirige directamente al cardumen hasta llegar a una distancia de 40 a 60 m, momento en que large el arte manteniéndose a la misma distancia del cardumen y dándole la vuelta hasta que está completamente cercado. Da el autor definiciones de la diversas clases de ecos recibidos en el sonar, que generalmente tienen un efecto perturbador en el reconocimiento de los trazos reales del eco de los peces. Los cursos de capacitación comprenden instrucción práctica en la búsqueda y mantenimiento del contacto con un cardomen y consisten en primera instancia en localizar un objetivo artificial y, más adelante, los cardúmenes verdaderos. Hasta el momento se han dado ocho cursos y se ha adquirido muchísima experiencia. Parece ser que debería darse más instrucción en los principios fundamentles, pero la capacitación en clasificación e identificación de los trazos de los ecos ha producido, en general, los resultados previstos.

by
G. Vestnes

Institute of Marine Research,
Bergen

DURING the post-war period acoustical instruments (echo sounders and sonars) were used more and more by the Norwegian fishing fleets. In 1949/1950 the echo sounder had its break-through as a fish detecting instrument; ten years later, sonar instruments as well were considered a necessity on a well equipped herring boat. Today we have reached the stage where purse seiners without a modern echo sounder and sonar have difficulty in getting a qualified crew.

When the sonar equipped research vessel *G.O. Sars* was commissioned in 1950, very few people believed that this type of instrument would ever become widely used on commercial vessels. However, the fishermen soon realized that their boats, equipped only with echo sounders, could not compare with the *G.O. Sars* in ability to locate fishable concentrations of herring. Consequently, the most far-sighted vessel owners started to provide their vessels with sonar instruments.

The need for instruction

The first sonar vessels did not have immediate success, probably because the skippers at first failed to master the proper operational technique. This shortcoming was soon realized by the fishermen and the fishing authorities were requested to arrange suitable instruction courses in the use of sonar. The Institute of Marine Research in Bergen, in co-operation with Simonsen Radio A/S, Oslo

was given the task of developing a general plan for such a course and preparing suitable instruction lectures.

The organization of the courses was conducted by the Office of Education and Training of the Directorate of Fisheries. The courses were published through newspaper advertisements. Participants had to pay their own fare and subsistence, but the course was otherwise free of charge.

The expenses for the classroom and training vessel were covered by the Directorate of Fisheries. Simonsen Radio A/S installed complete sonar and echo-sounding equipment in the classroom and provided experts from their sonar factory to lecture on the construction of the instruments. The author was chief instructor and in charge of the courses.

General pedagogic viewpoints

The average age of the fishermen participating in the courses was 40 years and, for most of them 5 to 45 years had elapsed since their last formal school education. It was therefore evident that the methods of instruction had to differ considerably from those applicable in a class of younger students.

Each participant was issued with a written compendium covering all lectures but was not expected to read and learn the contents in the fashion usually demanded in a normal school. The compendium was merely regarded as an aid to the memory and the main emphasis was laid on oral lectures in all subjects, with extensive use of slides, plates and blackboard. A strictly "correct" technical-scientific explanation was purposely avoided in all technical subjects for the benefit of a more easily understood popular description. In fact, technical subjects were only treated to the extent that they were regarded as strictly necessary for the operational use of sonar equipment and the courses were not aimed at training in maintenance and servicing of the instruments.

For instruction in the main subjects great emphasis was laid on frequent repetition of basic theorems and main viewpoints. Thus, each morning the first hour was used to repeat, discuss and sum up the lectures of the previous day.

It should also be mentioned that, again for pedagogical reasons, the lectures were purposely illustrated and "spiced" with references to factual episodes from the practical fisheries, and sometime also with stories from other fields (see detailed course timetable).

Detailed Timetable

First Day. 9-9.45 a.m.: Introduction; basic principles of sound; 10-10.45 a.m.: Sound propagation spreading, attenuation, refraction, reflection; doppler effect; 11-11.45 a.m.: Film; Principles of Sonar; 1-1.45 p.m.: Transducers for echo sounding and Sonar; 2-2.45 p.m.: Some basic principles of electronics; 3.30 p.m.: Principle of electronic valves.

Second Day. 9-9.45 a.m.: Repetition of yesterday's lessons; discussion; 10-10.45 a.m.: Valve-transmitters and receivers; 11-11.45 a.m.: Description of different types of echo-sounders; 1-1.45 p.m.: Classification of echo-sounding recordings (slides); 2-2.45 p.m.: Echo-sounding transducers; installation; 3.30 p.m.: Sonar transducers; installation.

Third day. 9-9.45 a.m.: Short discussion on yesterday's lessons; 10-10.45 a.m.: The importance of good maintenance on ship's electric power system; 11-11.45 a.m.: Using Sonar for fish finding and three other short spells.

Fourth and Fifth Days. Practical training with Sonar gear in classroom.

Sixth, Seventh and Eighth Days. Practical training at sea.

Basic principles of sound propagation in sea water

The velocity of sound in sea water, normally approximately 1,500 m/sec, is dependent on temperature, salinity and pressure. These factors vary but for echo sounders the effect of such variations is relatively small and the error introduced by assuming a constant sound velocity is hardly of any significance for practical fishing purposes.

The sound velocity increases with increasing temperature and with increasing salinity. Thus, for example, under conditions of decreasing temperature with depth, the top of the sonar beam will attain a greater velocity than that of the lower part. This results in a downward deflection of the beam and, consequently, a reduction in horizontal range. Such conditions are quite normal during summer in the Norwegian Sea. At other times of the year, and in other areas, conditions are different and it is easily understood that sonar conditions may vary greatly.

A more comprehensive treatment of this topic here is not necessary but it should be emphasized that sonar range, as a result of differences in hydrographic conditions, may be quite variable. Some knowledge about sound propagation in the sea is therefore essential in using sonar in the most efficient searching programme.

Search procedures

Location technique—Sonar search is carried out according to certain patterns. A first type of searching pattern is called "side to bow" (Fig 1A). The transducer is turned to between 70° or 90°, port or starboard. A sound pulse is transmitted and the transducer quickly turned 5° forward and kept in this position to allow sufficient time for possible echoes to come in. The length of time the transducer must stop depends on the scale range used. With a scale range of 3,000 m, the transducer must be kept pointed in the same position for two seconds for the soundwave to travel 3,000 m, and another two seconds for the echo to return. In addition, a dead period of approximately 0.5 sec is required before the next transmission. At a range of 3,000 m the sonar, therefore, will need 19 X 4.5 sec, or 85.5 sec, to search from 90° to directly ahead. If the ship is doing 10 knots (5.1 m/sec), it will travel 436 m forward while the sonar is searching one side. The transducer is then quickly turned to the opposite side and the programme is repeated.

A very common searching pattern is the so-called "side to side" method (Fig 1B). This pattern also starts with the tranducers at between 70°–90° on the bow, and the sweep alternates from one side to the other.

Fig 1C shows a searching pattern called "side to side and back". This method differs from "side to side" only in that the transducer is quickly turned back to the

starting position as soon as both sides have been searched.

Figs 2A, B and C, which were obtained at vessel speeds of 5, 10 and 15 knots respectively, show situations where the searching pattern is "side to bow". The range scale is 3,000 m and the sonar range is 500 m. The figures show that the search leaves pockets of the area uncovered, either because the range scale was too large or, alternatively, because the speed of the ship was too great.

From Figs 1A, B and C it can be seen that the various searching methods differ in efficiency in obtaining complete coverage.

The three search patterns mentioned are those most commonly used. In localities where many vessels are operating simultaneously, the skippers will have to modify the searching methods to minimize the effects of disturbance from other vessels.

Catching technique—The sonar catching technique varies with the type of gear the vessel is using.

For pelagic trawl fishing, the technique is to point the ship towards the fish concentration. When the concentration is below the ship the echo sounder will show the depth and the trawl depth can then be adjusted accordingly.

A dory-equipped purse seiner uses the sonar to direct the fishing master to the fish concentration. When he has found the concentration he directs the dories with the aid of his own small sonar (Basdic) installed in the

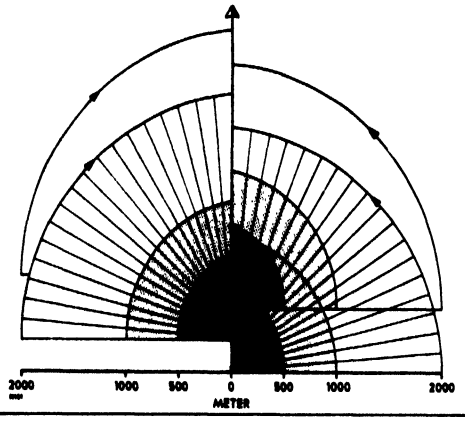


FIG. 1A

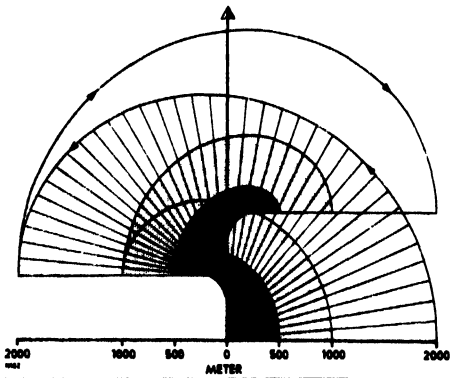


FIG. 1B

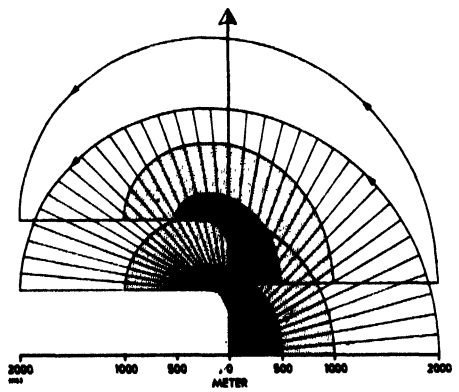


FIG. 1C

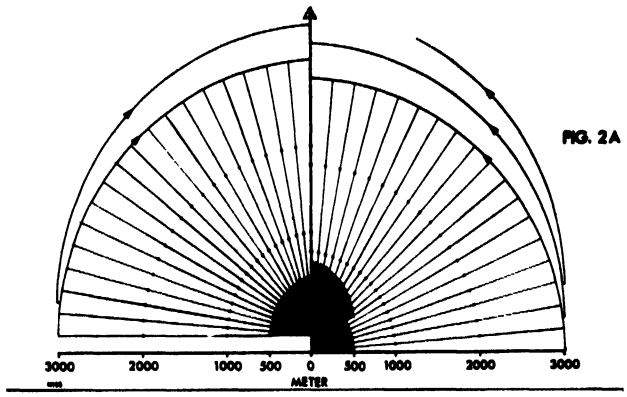


FIG. 2A

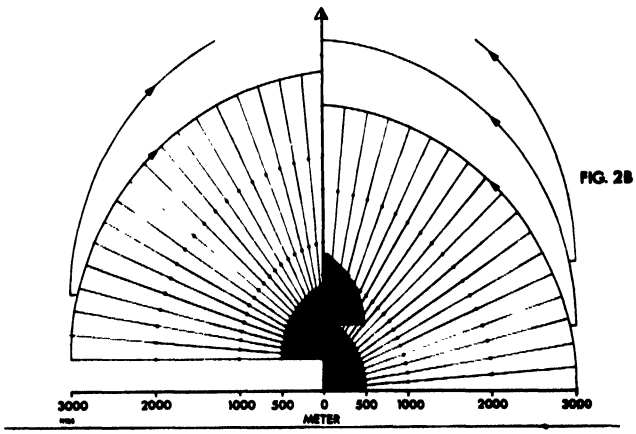


FIG. 2B

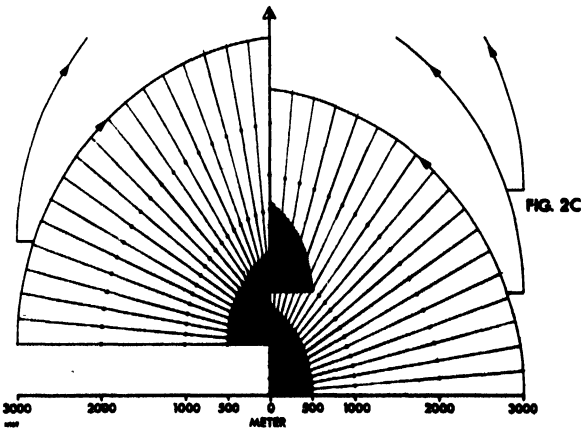


FIG. 2C

dory, in the catching procedure.

The most advanced sonar catching technique is that of a stern purse seiner. When the fish concentration has been located by the searching technique, the ship moves towards the concentration. The skipper, who is now alone in the wheelhouse, keeps contact with the concentration. When the range has decreased to between 40 and 70 m he gives the order to start setting the seine. This is a very critical moment and the skipper has to be skilled if the operation is to be successful. With the aid of sonar he keeps the same distance to the concentration while it is being surrounded.

This technique is widely used in the fisheries for herring near Iceland and also in the coalfish fisheries in north Norway.

Classification and identification of echo traces

For the fishermen, the transition from interpretation of echo sounder recordings to sonar traces is difficult because in sonar the third dimension is being dealt with. The ocean contains a great number of objects which present themselves as good sonar targets but only very few of these are concentrations of fish. A number of these have been classified and given special names in the "sonar language":

(a) **Bottom echoes**—Echoes from peaks and other topographical irregularities. They often interfere with the echoes from fish in shallow waters (50–100 m).

(b) **Reverberation**—Echoes caused by tiny pelagic plants, animals and air bubbles in the sea. In the open sea (deep water) the rule is that the greater the distance from which the reverberation is recorded, the better are the sonar conditions.

(c) **Stratal Echoes**—Stratal echoes associated with large vertical or horizontal temperature gradients in the sea. Great attention should be paid to the existence of such conditions as they cause the sound beam to be refracted and thereby limit the sonar range.

(d) **Surface echoes**—This kind of echo varies with the seasons. It is less pronounced in the summer and most apparent in the fall. The surface echoes appear at distances from zero to a few hundred metres.

(e) **Shore echoes**—Shore echoes can be classified in the same manner as bottom echoes.

(f) **Wake echoes**—Wake echoes can be a considerable nuisance where many boats are operating in the same small area.

(g) **Wave echoes**—In rough sea with big breakers air will be "beaten" into the sea and cause the sonar beam to be reflected. If the sea is very rough, wave echoes may render the sonar useless.

(h) All fish give echoes, but to distinguish between echoes received from different species is a very complex matter. However, from the knowledge of differences in behaviour between the various kinds and sizes of fish in an area, it is sometimes possible to identify them by their echo traces. Until now, sonar has most frequently been used to detect herring, a typical schooling fish. In the future sonar will, no doubt, be used for other species as well. Herring schools vary in size and density but they all yield very good and distinct echoes. When herring appear on the spawning grounds, the fish usually spread out during the night but accumulate in dense schools during the day. At night, therefore, sonar is not a highly efficient search instrument on the spawning grounds, whereas in daytime it is often quite effective.

Practical instruction at sea

For practical sea training, an ordinary Norwegian herring purse seiner of approximately 140 ft (approximately 300 tons), equipped with echo sounder and SIMRAD herring asdic, was used. Because of limited space, it was necessary to keep a strict timetable and good discipline to give each man personal attention.

The training area chosen was an inshore locality with little traffic and where temperature conditions permitted good sonar conditions to be obtained with a range of approximately 1,500 m.

Measurements of temperature gradients and judging the resultant sonar conditions were part of the training programme.

The training was carried out on artificial targets, using a 1 m triplane as the target object. The depth of the target was adjusted according to sonar conditions, but in most cases the target was placed at a depth of approximately 15 m with a marking buoy on the surface. All participants had to serve in turn as skipper, helmsman and sonar operator. This training was considered essential to enable the trainees to fully appreciate the necessity of close co-operation and to see to what extent success is dependent on the skill and experience of these three. During the first day of sea training, moderate speed (4–5 knots) and helm were used in order to let the participants practise methods and co-ordination in slow motion.

All runs were commenced at a distance of about 1,000 m from the target and the first exercise was to locate the target applying the standard searching methods discussed in the classroom. Thereafter the vessel was manoeuvred towards the target following the information obtained by sonar. Each complete run, including a subsequent discussion and criticism, had a duration of about 20 min. On the second day at sea the speed was increased to about 8 knots and the exercise consisted of locating a herring school (i.e. the target) but without the procedures necessary for the actual catching.

On the third and last day variable speed (10–0 knots) was used and the complete sonar procedure for locating and catching with purse seine was carried out.

The last phase of this procedure, which may be termed the "attack" phase, differs according to whether the seine is shot from the main vessel or from two dorries, and training was given in both methods.

General experiences from courses

The number of pupils varied but classes of approximately 20 pupils were most suitable.

It was generally agreed that an introduction to the

basic principles of underwater ranging and sounding was absolutely necessary in order to make full use of the possibilities of the sonar equipment. In addition, the limitation caused by the varying environmental conditions must be fully understood. In future courses the lessons on fundamental theories should be given a broader foundation.

The lessons given on classification and identification of echo traces were evidently very useful. For efficient instruction in this difficult field it is necessary that a good supply of verified echo traces be available.

Some fishermen have, without receiving any instruction, arrived at successful methods of search procedure and sonar catching technique. However, the trial-and-error procedure necessarily takes a long time before efficiency —one to two years.

The importance of quick and precise handling of the sonar controls should be stressed. A standardized procedure of communication between the skipper, helmsman and sonar operator is also important. Rapid manoeuvring is absolutely necessary because of current, wind, movements of the fish school and also because of competition on the fishing ground. Moreover, in the catching phase all relative movements are very fast since the ship is close to the school.

It is not possible in a short course to educate skilled sonar operators but, with some training under sea conditions and with experienced instructors, a foundation is laid which will be useful to the fishermen in the continued training aboard their own ships.

E. A. Schaefers

Discussion on Purse Seining

Mr. E. A. Schaefers (U.S.A.) Rapporteur: Purse seines have played an important role in the fish production of various nations throughout the world for many years. Recent developments, such as those described in Paper No. 79 by Jakobsson on purse seining for herring in Iceland, and the oral comments on anchovetta in Peru by Valdez during earlier sessions, as well as developments elsewhere, indicate this method may play an increasingly important role in the future.

The Icelandic fishery was a typical inshore one utilising the traditional Norwegian two-boat dory system up to 1944. Then, however, migration and behaviour patterns of north coast herring changed drastically and the fish were not available to the traditional gear. The catch from purse seines dropped from about 200,000 tons in 1944 to 10-40,000 tons afterward. That collapse forced a change from the two-dory system to a one-dory system, which was replaced by the present system utilising only the main boat.

The present method as described by Jakobsson is the result of many inter-related factors, including organised fish searching with horizontal echo-ranging equipment (asdic or sonar), a new technique in asdic-guided purse seining for deep swimming schools, mechanised handling of the nets by power blocks and the use of deeper and stronger seines made of nylon netting hung to 'Terylene' ropes. Asdic was first used on Icelandic grounds by a Norwegian research ship in the early 1950's and was first installed in Icelandic commercial fishing boats in 1954. Since then, many fishermen have learned to shoot purse seines around deep swimming schools and after 1958 the method became fairly widespread. In 1962, three vessels using asdic searched the fishing area continuously and reported the location of fish to the fleet. It is agreed by fishermen that over 50 per cent of the 1962 record herring purse seine catch of 482,000 tons stemmed directly from this work.

The methods now in use did not happen overnight. Considerable effort was expended in adapting the power block to the typical Icelandic vessel which has the wheelhouse very far aft. Experiments in 1959 concerning shooting and hauling the net from the upper deck aft of the wheelhouse were successful and that arrangement has been used throughout the Icelandic fleet, with the exception of boats less than 85 feet long which have no upper deck. On these, enough space was provided aft of the wheelhouse and in the starboard passageway.

The potential value of sonar for locating fishable concentrations of herring was also realised in the early 1950's by Norwegian fishermen following experiments aboard the research vessel *G. O. Sars*. Vestnes indicates that although vessel owners soon began to equip their vessels with sonar, these vessels were not immediately successful. It was felt this was probably because the skippers at first failed to master the proper operational techniques. Accordingly, a course of instruction in the use of sonar was organised by the Institute of Fisheries Research in Bergen, in co-operation with a commercial firm. This eight-day course, followed by additional experience aboard ship, has resulted in the development of skilled sonar operators in considerably less time than the one to two years required through the trial and error procedure.

I am certain that much more will be heard concerning developments in purse seine fishing throughout the world. I know research and developmental efforts on this type of gear, for various species of fish, have been underway off the United States east coast, Chile, Peru and other places. These efforts have, in many cases, gone beyond the experimental stage and have resulted in totally new fisheries or in increasing the efficiency of the gear in existing fisheries. Along the east and Gulf coasts of the United States the menhaden industry has adopted several new developments which have improved the efficiency of this fishing method. Two of these were the power block for retrieving the net and the mechanical net lift from the topping boom to dry out the fish in the centre or bag section of the net so that they could be pumped into the carrier vessel more economically. Some additional developments adopted by the industry which have contributed to a more efficient operation include the automatic pilot, two-way radio-telephones for communication between the spotter aeroplane, carrier vessel and purse boats, and hydraulic-ram operated boat falls for raising the purse boats.

The conversion, and subsequent success, of the California based "clipper" fleet of pole and line tuna vessels to purse

seiners has been well documented. We should like to hear more concerning these and other efforts from the various experts assembled here.

Mr. R. F. Allen (U.S.A.): I think the Icelandic fishing methods described in Mr. Jakobsson's paper might be improved by use of a heavy weight on the bottom purse line to enable the net to be pursed at a lower depth than can be accomplished when the weight is evenly distributed along the net. In the menhaden fishery, as carried out by two boats, they have a tom weight of approximately 700 pounds, which slides down the purse line from the purse davit after the seine is set and the two purse lines are hooked to the winch. The weight enables the net to be pursed at a lower depth which would be of considerable advantage when the herring purse seines go down to 30 to 35 fathoms. This system was used and abandoned in Iceland about 20 years ago but recent changes indicate it should again be considered. Purse seining for menhaden has been highly mechanised with two-boat operations and there has been little attempt to use the one-boat system, at least to date. In South American waters a big Norwegian vessel, of 350-ton capacity, recently operated with two purse boats and caught some 32,000 tons of anchovetta in 8 to 10 months. Because of the different labour conditions and other factors it is possible the operation was not a financial success. Subsequent vessels used a system similar to the Icelandic purse-seining methods but they had not proved completely applicable. The anchovetta were very difficult fish to bring up to the surface to concentrate for brailing—more difficult than herring or South African pilchard. That put a great deal of strain on the nets which made it difficult to use the power block as a method of concentrating the fish in the net. In the typical South American craft winches were used and the strain was terrific during their operation. He thought a number of additional refinements could be made in purse seining, particularly in relation to tuna seiners which handle nets that weighed up to 20 tons. Purse seining for tuna is also being attempted in African Atlantic waters. A number of changes are taking place in present techniques to adjust to the different fishing conditions found in that area. He would like to know more about those changes because the American vessels fishing in those waters had not been eminently successful.

Mr. B. Petrich (U.S.A.): While the principles of purse seining are more or less the same the world over, conditions vary. For example, he had been asked whether the Icelandic net would be good for tuna fishing. He thought it could be in principle but various problems must first be overcome, particularly with regard to drying up the fish. Several suggestions have been made for solving these problems, but they have not been tried under actual fishing conditions. One suggestion he mentioned was concentrating the fish by using lines working as an endless belt through the power block. When the weight of the fish becomes excessive, attach a hook to the endless line, and with straps attached to the net, bring it into the winch. It might be necessary to use the West Coast type of strap to get the fish close enough to the surface for brailing. He pointed out that tuna purse seines of very large size are now being made. One, which he had just helped make, weighed 30 tons before treating the net. Vessels operating these are from 1,100 to 1,200 tons which usually have a seine skiff at least 30 feet long. The use of such a large net is possible only because of the advances over the years in the strength of winches, nets, cables and, of course, introduction of the power block. He told of one haul of 350 tons of tuna which was handled with little difficulty. Purse seining for tuna is now more successful by fishing deeper, and they are now developing even deeper but much lighter nets for use in African waters. They had been working at depths of 35 fathoms but were now getting down to 50 fathoms. He thought purse seiners needed heavier winches and that this was perhaps one area where they had fallen behind. Although some winches were 50, 75 or even 100 hp they could be made much larger and more powerful. With larger winches it would be possible to use half-inch cable instead of three-eighths-inch cable. This would give extra strength and additional weight to help take the net down to maximum depth. Successful purse seining under today's conditions for big fish such as tuna means they must have very strong boats, strong equipment and all necessary supplementary power.

Mr. Jakob Jakobsson (Iceland): I want to emphasise that special asdic research in Iceland was begun in 1950 by the Norwegian research vessel, and was first used by our commercial fleet in 1954. With reference to the power block not being successful because of the heavy weight in the net, he would like to ask why could it not be used to bring the net up a certain distance and then turn to the old methods for the last part of the net?

Mr. R. Lenier (France): He described purse seining experiences for tuna in Atlantic tropical waters. One French vessel had caught 500 tons and he emphasised that for fishing this area they must get the right type of boat for the job. Speaking of one model for a tuna vessel he had seen, he considered it would never be able to do purse seining because the decks were cluttered up with wells for live bait.

Mr. Mareschal (France): You cannot judge a boat from a scale model. The model to which Mr. Lenier referred was a clipper built craft and it could easily be changed into a purse seiner. All that needed to be done was to remove the live wells and put up a platform and place a power block in the proper spot.

Mr. R. K. N. Ocran (Ghana): In our experience all nets need to be adjusted to meet local conditions. One expert who had criticised their own practice of 30 per cent slackness in the web found that the heavy net he recommended got stuck on their rough grounds. Similarly, others who had originally criticised their nets changed to the Ghana system after gaining some local experience. In Ghana they were now using a Black Sea type of purse seine. It was smaller, with heavy purse rings but no leadline and the damage to their nets on rough grounds had been reduced considerably. They used a helper boat—an 18-foot motorboat with a 22-hp engine which cost about £2,000. Sometimes water currents in the fishing area ran to the east and the fish went to the west, with the wind yet in another direction. Because of the nature of these conditions, unless they had the helper boat, they would find fishing too difficult to be practicable. Those who were going to develop and build equipment for use in Ghana should first study conditions there.

Dr. Haim Levy (Morocco): One problem that we have in purse seining for tuna is the difficulty of pulling in dead fish lying at the bottom of the net. Sometimes we get a catch of 20 to 25 tons. We have then been compelled to call other boats to help. I would like information on how best to transfer tuna from the net to the deck of the boat when you have dead tuna lying at the bottom of the net.

Mr. Kentaro Hamashima (Japan): We are greatly concerned with the possibilities of mechanisation. In 1955 we discovered

a fishing ground in the East China Sea suitable for purse seining. This was an offshore operation which required a voyage of 20 to 25 days. The catch had to be delivered directly from the fishing grounds to market by means of carriers. We had to reduce the number of the crew and provide them with adequate accommodations on the boat. We considered the possibility of introducing the power block system. However, due to peculiarities of our net the power block did not suit our conditions, and we had to develop our own system in its place. The problem of hauling the net was solved by fixing a big V-grooved net roller onto the stern. The roller was driven hydraulically. In our first experiment, the roller was not properly made and the net was entangled on one side when hauled up. This problem was cured when we fixed rubber bands radially on the surface of the roller. By these methods we succeeded in reducing the number of crew from 30 to less than 17.

Subsequently an improvement was made by the addition of a horizontal net roller athwartship riding on raised rails on either side of the net bin at the stern of the vessel. This roller aids the flaking down of the heavy and very big net —up to 1000 fm long by 100 fm deep. With this latest method the net is still hauled aboard by means of the V-grooved sheave, and then passed over the power driven horizontal roller for stacking. (See Fig).

But we have two problems yet unsolved. In our experiments the total weight of the apparatus could not be reduced below four tons. As this affects the stability of the boat, there were both direct and indirect limitations to offshore operations. We are considering further possibilities of reducing the weight in the future. In the second place, a further reduction of manpower depends on how we can mechanically move our catch from our boat to the carriers. To do this we are considering the use of a fish pump.

Mr. S. Remoy (Norway): He pointed out the difficulty of the boat setting the purse seine net keeping out of the bay or bight of the net. In experimental purse seining in South-West Africa he had encountered the problem and it also existed in Norway. He had suggested that an air propeller should be mounted on top of the wheelhouse to provide the power to keep the vessel out of trouble and his inquiries showed it would take a 15 to 20-hp engine to provide the 1,800 or 2,000 revolutions per minute necessary. As it was, some Norwegian vessels were employing a second vessel to assist. This increased the cost of the operation.

Mr. Jean Frechet (Canada): To prevent vessels drifting towards the centre of the seine, we, in Canada, introduced water-jet nozzles. They are fitted beneath a vessel with pumps working from independent energy or from an electric motor. Such water jets develop from 500 to 2,000-lb thrust so by the addition of a number of them it has been possible to forget the use of tow boats normally used in this technique in order to take vessels out of the seine circle. Canadian vessels purse seining for herring had completely abandoned the use of turntables when they found that with an open deck they could handle a high purse net. This gave much more flexibility to the boat and better stability. He would like to know why, in many countries, turntables were still in use.

Mr. E. A. Schaefers (U.S.A.): Even some of the most modern and largest United States tuna seiners use turntables. We should not overlook the fact that there is considerable variation in the design of tuna seiners and, on some, the use of a turntable is necessary for efficient operation. Some tuna seiners even use two power blocks, one forward and one aft. Some seine fishermen probably still use turntables out of tradition.

Mr. Petrich (U.S.A.): In the United States, boats on the west coast use power skiffs to keep the big boat out of the net. These boats are equipped with 300 or even 400-hp engines. The skiff is also used in the brailing operation which makes the job much easier and safer. Turntables are used by some craft and not by others; there are reasons for both points of view. He personally thought there were advantages with the turntable—the structure of the boat and the room on deck all came into it. As regards the transfer of dead fish from the tuna net, he would be glad to personally explain the details of the procedure to Mr. Levy. There is no real problem provided fishermen have the experience and the proper equipment. As compared with the Moroccan catch of 10 to 25 tons, he had brought up 150 tons of dead fish in one shot.

Dr. Schärfe (Germany): We are interested in this method of fishing, although in Germany we have not had much experience in purse seining. Our new research vessel which will be basically a large sterntrawler will therefore also be equipped for both purse seining with a large purse seine from the big boat itself and with smaller purse seines according to the dory system. This may be an example where in my opinion the two-boat system is unavoidable. With a boat about 83-m long and a high superstructure it would be very difficult to purse seine a small and light net if there is any wind and/or currents. German experiments near Iceland with vessels of the small trawler size, show that this is already a problem and experiments along these lines have not been too promising. There seems to be a limit with regard to the size of the vessel up to which the one-boat technique can be successfully used. To cope with the problem of keeping a big vessel out of the centre of the purse seine they intend to use power dories as helper boats.

Their new research vessel, however, would be equipped with a Pleuger active rudder of 250 hp as well as a bow stream rudder of 400 hp that would give something along the lines of the Canadian device for keeping the vessel out of the circle. These devices would provide 650 hp to push the boat from the net. He had heard the Norwegians had used a new-style rudder and had found the net was fouled. He was therefore relieved to hear that the water-jet system worked in Canada. What size were the Canadian vessels that were kept out of the net by the 2,000-pound water jets?

Mr. Frechet (Canada): The system was originally used on very small boats, mainly 45 to 55 ft in length, but recently it

had been installed on a 91-ft steel tuna purse seiner which is still under construction. We hope good results will be obtained.

Mr. H. Kristjonsson (FAO): Referring to drawings of the new Icelandic purse nets shown in Jakobsson's paper, he called attention to the fact that the net tapered sharply towards the bunt end. The reason for this was that while the power block could pull in the net lengthwise (i.e., pull on board the wing and main body), it could not be used for "drying-up" the net under the bunt. On conventional rectangular nets this required hand labour and was time consuming. In Iceland a rational solution was found in simply eliminating the net below the bunt, which served no useful purpose anyway. Consequently the power block could be used to crowd the fish in the suitably shallow bunt end so it could be brailed with little or no manual "drying-up". This saved not only labour, but also time which was of even greater importance when handling big catches in difficult sea conditions, and helped to avoid trouble from the fish dying and sinking to the bottom of the net. He thought this feature could be adopted advantageously in other purse seine fisheries where power blocks were used.

Mr. J. Jakobsson (Iceland): Under normal conditions and even in considerable current, the Icelandic fishermen managed quite well without any help from other vessels. I think this is due primarily to their skill in ship handling and their complete understanding of wind, current and sea. There may be conditions when their chance of a catch is much greater if they shoot in such a way that there is danger of the boat becoming entangled and a skiff might be necessary to prevent this. A film which he could show revealed this very clearly but in those cases a small skiff was usually quite sufficient to pull the ship away from the net or the net away from the ship. He was, however, very interested in the use of water jets and air propellers, and any other devices which might be considered.

It would be much easier for the captain to press a button and get things going than to have to lower a skiff. In one-boat power block fishing there was an enormous difference in relation to individual nets. Some nets tended to fall into a bad shape whereas other nets were much easier to purse.

Mr. Valdez (FAO): In Portugal they use auxiliary boats to avoid the boat becoming involved with the net. Another reason is that whenever big catches are caught the small boats can help with the catch and, further, those small boats act as carriers of the fish to port while the main boat stays on the fishing ground. The use of the second boat is really very economical and is generally practised wherever there is Portuguese influence. In Peru they were using only United States gear but in Chile they had the Icelandic type, the Norwegian type and the United States type. The Norwegian vessel with two dories had done very well lately, averaging 350 tons per day, while the local boats had averaged 60 tons. The most common boat in Peruvian fishing is 65 ft long. They also have the problem of fishing in shallow water. Fishing goes on all the year but there are two big seasons, one in December/January and the other in June/July. A new, promising fishing ground had been discovered but it had a rough bottom and the fishermen were afraid to go there for fear of damaging their nets. He was interested in discovering a gear which could be used for fishing such rough ground.

Mr. Schaefers, Rapporteur, summing up: When I noticed that there were only two papers on purse seining when there were evidently so many developments going on throughout the world, I was apprehensive that this important method of fishing would not be thoroughly discussed. My apprehensions now appear to have been groundless and we are thankful to all of you who have enlightened us as to the various methods used throughout the world.

After recapitulating the points made by each speaker, Mr. Schaefers gave a résumé of events that led to the development of a purse seine fishery for tuna in New England. Sporadic attempts began in the late 1930's but a variety of conditions interfered with the operations. Such things as hurricanes, differences of the schooling habits of the fish from year to year—all these factors led to unsuccessful initial attempts. In 1958, however, a 62-ft Gulf of Mexico shrimp trawler was rigged to tuna purse seining. Conditions that year were favourable and the fish appeared in abundant schools so that a successful season was experienced by this particular vessel. Since that time other vessels have entered this fishery and although it is still small in relation to the total world tuna catch, more vessels are entering the fishery each year. It was quite apparent that the development of purse seining was still taking place throughout the world. It must be adapted to local conditions; a fact which cannot be over-emphasised.

The Application of Hydraulic Power to Fishing Gear

Abstract
Hydraulic systems for fishing vessels may be classified as low pressure (200 to 550 psig), medium pressure (1,000 to 2,000 psig) and high pressure (3,000 to 5,000 psig). Of these, medium-pressure systems are generally favoured in the United States because of equipment availability. Of the two basic types of systems, the open loop system is favoured over the closed loop system because it is more adaptable to driving a number of different devices. The principal advantages of medium pressure hydraulic power for fishing vessels over other types of power are: small size, light weight, reliability, performance under varying conditions and the wide degree of control available. Pumps convert rotary mechanical power from electric motors or engines to flowing fluid under pressure. Hydraulic motors convert the fluid power to rotary mechanical power; hydraulic cylinders convert the fluid power to linear mechanical power. The front power take-off on the main engine is the most common method of driving hydraulic pumps in small fishing vessels, although on some of them, such as gillnetters or seine skiffs, automotive power steering pumps are directly connected to the engine to drive reels or rollers. Larger vessels that have sufficient generating power to drive electric motors often use electro-hydraulic power units. The oil reservoir or tank usually has a capacity in gallons equal to the gallons per minute flow in the system. Double bottom tanks should not be used as reservoirs because they are impossible to clean adequately. The most important factor for the protection and long life of hydraulic pumps, motors and control valves is the maintaining of clean oil at all times. Hydraulic power installations vary from simple single pump systems to compound pump systems, depending on the type of vessel. Illustrated examples are given of hydraulic gear handling machinery, such as gillnet reels and longline; a number of power units on a modern purse seiner including a power block, purseline winch, corkline winch, anchor winch, brailing boom winch, boom vang winches, etc., many of which are remotely operated from a control console; also crab pot haulers on hydraulically activated boom; salmon purse seine reel; as well as deck machinery on a drumtrawler.

Applications de la puissance hydraulique dans la pêche

Résumé
Les systèmes hydrauliques employés sur les bateaux de pêche peuvent être classés en basse pression (13,6 à 37 atm), moyenne pression (68 à 136 atm) et haute pression (210 à 340 atm). Le système à moyenne pression est généralement utilisé aux Etats-Unis parce que l'équipement est disponible. Des deux principes de base, le circuit ouvert est préféré au circuit fermé parce qu'il est plus facile à adapter pour faire fonctionner en même temps, plusieurs appareils. Les principaux avantages de la puissance hydraulique à pression moyenne, pour les bateaux de pêche sont: petites dimensions, légèreté, sûreté, bons résultats sous des conditions variées et grandes possibilités de contrôle. Les pompes convertissent la puissance mécanique rotatrice, venant des machines ou moteurs électriques, en puissance fluide sous pression. Les moteurs hydrauliques transforment la puissance fluide en puissance mécanique rotatrice; des cylindres hydrauliques transforment la puissance fluide en puissance mécanique linéaire. Dans les petits bateaux on prend généralement la puissance directement de la machine principale pour actionner les pompes hydrauliques, bien que sur certains, comme les bateaux pêchant au filet maillant et les skiffs de senne, les pompes de commande automatique sont reliées directemente à la machine pour actionner les tambours et les rouleaux. Les grands bateaux qui ont assez de puissance génératrice pour faire fonctionner les moteurs électriques utilisent souvent des unités de puissance électro-hydraulique. Les réservoirs d'huile ont normalement une capacité en litres égale à l'écoulement en litres par minute du système. Les réservoirs à double fond ne devraient pas être utilisés parce qu'il est impossible de les nettoyer complètement. Le facteur le plus important pour la protection et la durée des pompes hydrauliques, des moteurs et soupapes de contrôle est de maintenir l'huile constamment propre. Selon le type de bateau, les installations de puissance hydrauliques varient du système à une seule pompe, simple, à des systèmes de pompes complexes. Des illustrations donnent des exemples de machines hydrauliques pour manipuler les engins comme les tambours à filets maillants et palangres, les unités de puissance d'un senneur moderne comprenant un power-block, un treuil pour ligne coulissante, un treuil pour ralingues à liège, un treuil, d'ancre, un treuil pour actionner les bigues, etc., et dont plusieurs sont actionnés à distance depuis un tableau de contrôle ainsi que les leveurs de nasses montés sur les biques actionnés hydrauliquement, les tambours pour les sennes à saumon et les machineries de pont sur un chalutier à tambour.

by
D. W. Lerch

Marine Construction & Design Co., Seattle

La aplicacion de la fuerza hidraulica a los equipos de pesca

Extracto
Los sistemas hidráulicos para embarcaciones pesqueras pueden clasificarse como de baja (200 a 550 lbs/pulgada^2), mediana (1.000 a 2.000 lbs/pulgada^2) y alta presión (3.000 a 5.000 lbs/pulgada^2). De éstos, los sistemas de mediana presión se prefieren en los Estados Unidos por la facilidad con que se encuentran en el comercio. De los dos tipos básicos, el de derivación abierta se prefiere al de derivación cerrada porque es más a propósito para accionar diversos dispositivos. En el caso de los barcos de pesca, las ventajas principales de la fuerza hidráulica de presión mediana sobre otras clases de fuerza son: pequeñas dimensiones, poco peso, seguridad, rendimiento constante en condiciones variables y amplitud de regulación. Las bombas transforman la fuerza mecánica circular de los motores eléctricos en un flúido que se mueve a presión. Los motores hidráulicos transforman la fuerza del flúido en fuerza mecánica circular y los cilindros hidráulicos la convierten en fuerza mecánica rectilínea. Una toma de fuerza del motor principal es la manera más corriente de accionar las bombas hidráulicas de pesqueros pequeños, aunque en algunos de ellos, como los que emplean redes de enmalle o los auxiliares de los cerqueros, las bombas automotrices se conectan directamente al motor principal para mover rodillos o carreteles. Las embarcaciones mayores que generan fuerza suficiente para mover motores elétricos emplean con frecuencia grupos electrohidáulicos. La capacidad del depósito de aceite es por regla general igual al flujo en litros por minuto en el sistema. No deberían emplearse depósitos de doble fondo porque es imposible limpiarlos bien. El factor más importante para proteger bombas. motores y válvulas de regulación hidráulicos es mantener el aceite siempre limpio. Las instalaciones hidráulicas varían desde la bomba única sencilla a sistemas compuestos de varias bombas, según la clase de barcos. Se dan ilustraciones de dispositivos para manipular sistemas hidráulicos como los empleados en los carreteles de las redes de enmalle y de los palangres, y de varios motores hidráulicos usados en un cerquero moderno que comprenden el motón mecánico, la maquinilla de la jareta, la de la relinga de corchos, el molinete, la maquinilla de la botavara de los salabres, la maquinilla de las ostas de la botavara, etc., muchas de las cuales tienen telemando en un cuadro central; asimismo se dan ilustraciones de haladores de nasas en una botavara hidráulica, el carretel de un arte de cerco para la pesca del salmôn y a lmaquinaria de cubierta de un arrastrero.

1. INTRODUCTION

The history of industrial revolution in all extractive industries such as mining, farming and lumbering has

shown a transformation from manual labour to mechanisation. Machines, such as the wheat combine or the mining machine that can dig a hole 20 feet in diameter through the side of a mountain, have been developed to permit fewer men to produce more for the greater good of all. The fishing industry, basically an extractive industry for the harvest of a natural resource, is one of the last industries to mechanise. It is only natural that we today see a tremendous expansion in fisheries technology and the development of improved boats, mechanised gear and better tools for search, harvesting, preparation and marketing.

Progress in fishing gear development, as in all other marine industries, is slow because of the conservatism of seafaring men. Nevertheless great strides have been made in the application of power and mechanisation on board fishing vessels (McNeeley, 1961). These advancements, together with the fruits of other technologies such as more reliable engines, remote controls, alarms and warning devices, electronic gear and so forth, enable the unit effort per crew man to reap richer harvests from the sea. Higher productivity, lower costs and greater profits lead to expansion, increasing economy, higher standards of living and more jobs.

Physiological studies have shown that a man can develop approximately one-half horse-power for a 30-minute duration. Peak bursts of energy for extremely short periods in a well-conditioned athlete perform work at the rate of two to three horse-power. Let us assume our man weighs 160 pounds and occupies at least 12 cubic feet aboard a vessel. If this one man is replaced with hydraulic power, we can supply as much as 12 horse-power—or the equivalent of 24 men as far as work being accomplished is concerned. Of even greater importance is the fact that hydraulic horse-power is available continuously, day and night, not subjected to periodic fatigue and exhaustion.

This paper will deal with a small facet of the general industrial revolution sweeping the fishing industry; that is, the application of medium pressure hydraulic power for fishing gear.

2. CLASSIFICATIONS OF HYDRAULIC SYSTEMS

For the purposes of this paper hydraulic systems will be classified as follows:

2·1 Low pressure—200 to 550 psig (28 kg/cm² to 39 kg/cm²). This type of equipment is characterised by large pumps and motors, direct coupled and turning at slow speeds. The pumps, normally direct driven by a slow speed engine or through gear reducers, operate at between 200 and 400 revolutions per minute. The pumps weigh about eight to 15 pounds per horse-power. Due to the low pressure a considerable volume of oil must be circulated in order to produce the required horse-power, consequently the piping lines are large in diameter in order to minimise the pressure loss caused by high oil velocities. A total cumulative pressure drop in the system of 50 to 100 pounds per square inch can rob the transmission system of 25 to 30 per cent of the total horse-power. One of the most desirable features of the low pressure system is the quietness of operation because the motors are low in speed and no gears are required between the motor and the winch. These low pressure systems have proven very reliable and satisfactory, particularly in the high horse-power ranges (Anon., 1962). Normally the winch and pump are made by one manufacturer and designed for a particular job. When more than one winch is used on a vessel, the winches are piped up in series so that the oil flows first from one winch, then to the next winch, etc., and back to be recirculated by the pump. The large size piping and control valves mounted directly on each winch preclude, to a great extent, the ability to provide simple remote controls.

Figure 1 illustrates the relationship between pressure, volume and horse-power.

2·2 Medium pressure—1,000 to 2,000 psig (70 to 140 kg/cm²). This type of equipment is generally favoured in the United States due to the commercial availability of motors, pumps, control valves, cylinders and associated equipment. The equipment used for the powering of fishing gear falls generally into three classifications—farm, mobile, and industrial. The "farm" type equipment is limited to valves and cylinders. Cylinders are available with stainless steel rods for corrosion protection but otherwise there is little attempt to produce corrosion-resisting equipment. The "mobile" classification includes pumps, motors, valves, power boost steering cylinders, filters, etc. Mobile valves are available with a limited number of spool configurations; however, they have exceptionally good throttling characteristics and are very widely used in marine applications. The "industrial" classification of equipment includes pumps, motors, cylinders and all of the more sophisticated valves. With pressures four to five times greater than the low pressure system the oil volumes required are from 20 to 25 per cent as great, consequently smaller pipe lines may be used. For instance, up to 100 horse-power can be handled with one and one-half inch pipe and hydraulic hose.

2·3 High pressure—3,000 to 5,000 psig (210 to 350 kg/cm²). This type of equipment is normally used in the United States for high horse-power cargo winches, steering gears, windlasses, etc. In order to utilise such high pressures, expensive piston type pumps and motors are necessary. These pumps and motors have extremely fine tolerances and consequently are extremely susceptible to any dirt in the system. The manufacturers of this type of equipment require full filtering of the oil to 10 microns (0·0004 inches). This requirement for such fine filtration produces extreme problems on a fishing vessel, and indeed, sometimes for the manufacturers themselves; consequently the most successful systems have been the "containerised" or packaged units (Short, 1959). These units utilise an electric motor driving a variable displacement pump in a closed loop transmission system to a hydraulic motor. The pump motor, valves, controls and tank are all mounted on a common

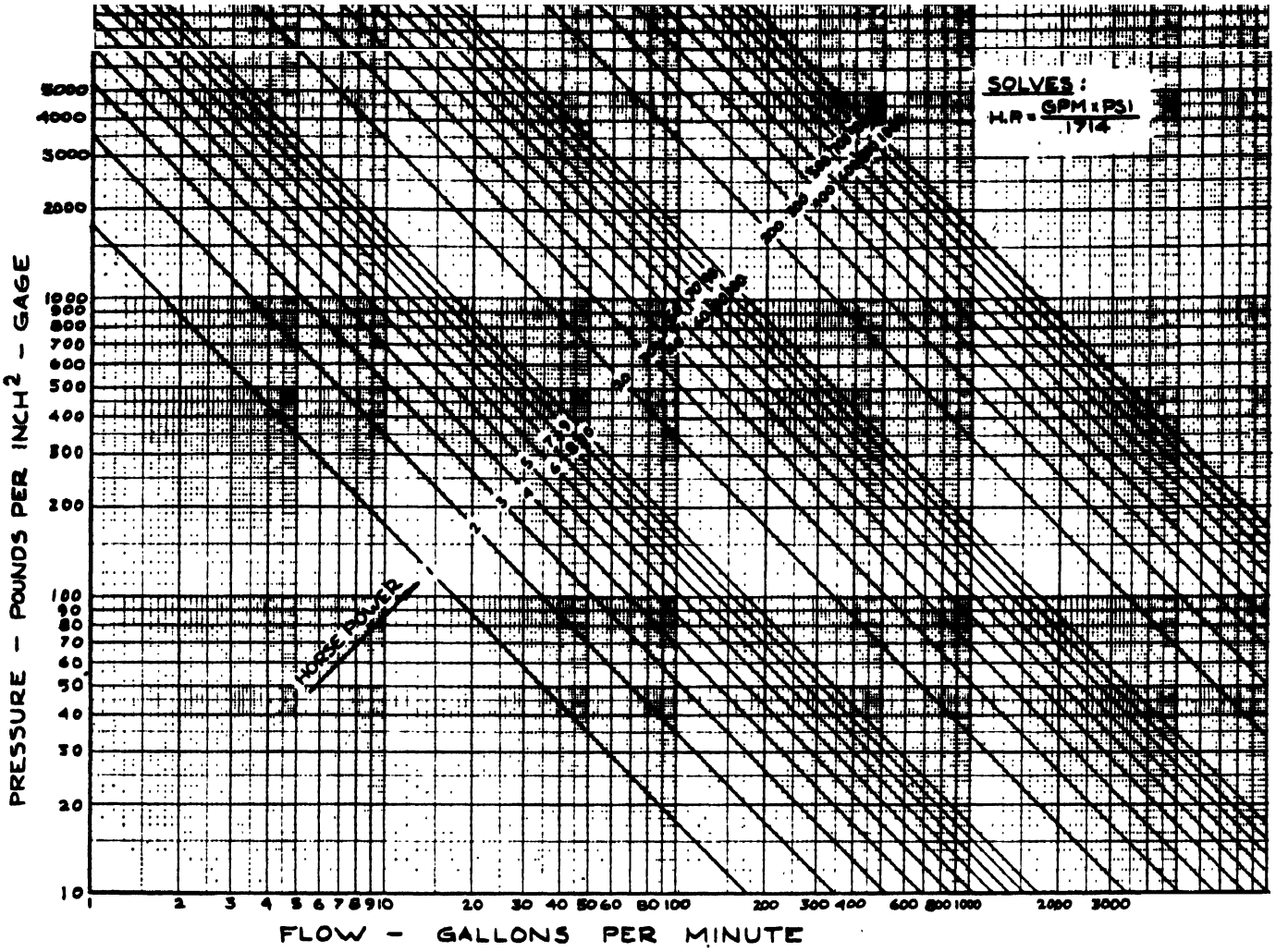


Fig. 1. Graph of hydraulic horse-power.

sub base with the winch, tested and filled with oil, thus ready to be placed on board ship needing only the electrical connections to the motor to be ready to operate. The manufacturer in this manner has complete control and responsibility for any dirt in the hydraulic system.

It is only the very occasional fishing vessel that is equipped with piston type equipment. Some large heavy duty seine or trawl winches are driven by low speed, high torque, large displacement, radial piston motors to reduce the amount of reduction gear required. Piston pumps and motors weigh between three and 10 pounds per horse-power and cost roughly two to six times as much as medium pressure vane type pumps and motors of comparable power.

3. TYPES OF HYDRAULIC SYSTEMS

Before progressing further with the discussion of hydraulic circuits, it is desirable to refer to Appendix 1, Standard Graphical Symbols. These symbols, called JIC symbols, were developed by the Joint Industry Conference, a group of American industries that have banded together to establish specifications and standards.

Most hydraulic valves are spool type valves—that is, a spool is moved within the housing to provide the various functions, such as directional change, response to pressure, relief valve discharge, etc. The rectangular block in the JIC diagram represents the spool. Appendix 2 compares some of the most useful JIC valve symbols, with schematic drawings of actual valves.

3·1 Closed loop system

There are two basic types of circuits, the first of which is the closed loop system (Figure 2). This is most common for fixed transmissions where the pump is a variable volume pump and the stroke is controlled over centre to reverse the motor. A small supercharging pump keeps a positive pressure on the pump suction. A relief valve normally set between 50 and 100 psi maintains a constant pressure which is fed to the suction side of the pump through the crossed check valves. An overload relief valve, again supplied by crossed check valves, protects the system from overload.

3·2 Open loop system

Opposed to the closed loop system is the open loop system (Figure 3). Here the pump takes suction from the tank, the discharge is directed to the motor through a directional control valve and the oil returns directly

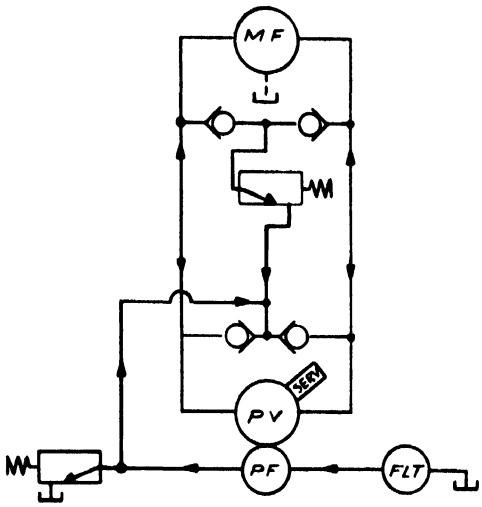


FIGURE 2
CLOSED LOOP SYSTEM

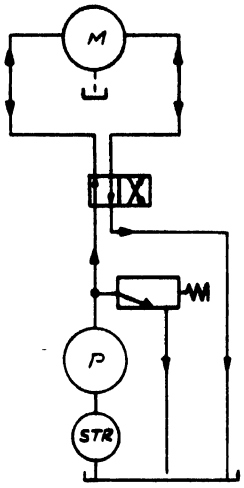


FIGURE 3
OPEN LOOP SYSTEM

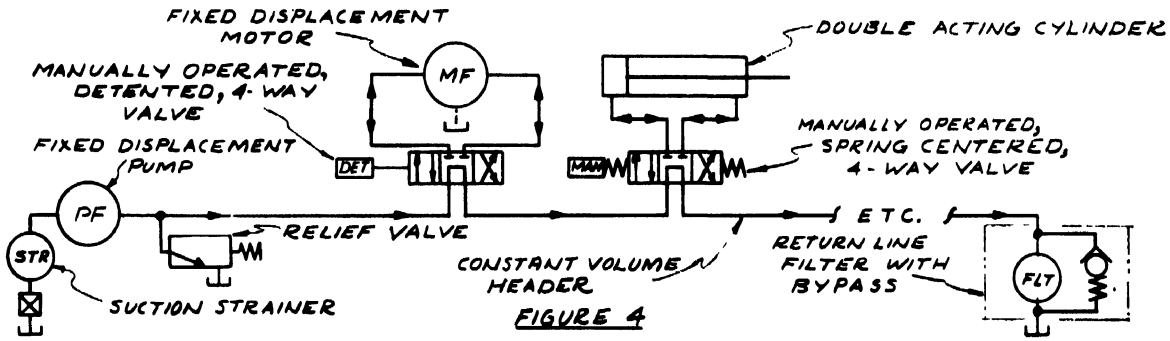


FIGURE 4
TYPICAL OPEN CENTER, SERIES CIRCUIT

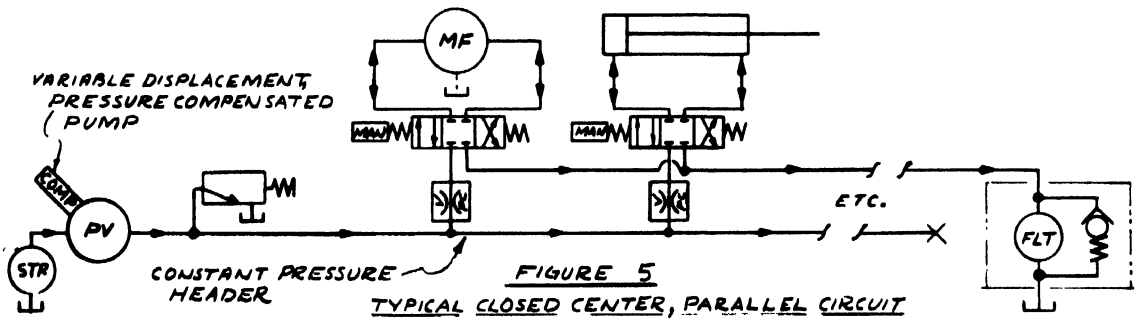


FIGURE 5
TYPICAL CLOSED CENTER, PARALLEL CIRCUIT

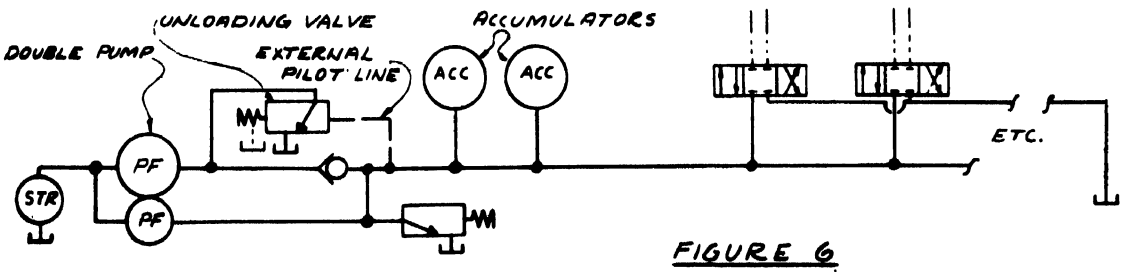


FIGURE 6
TYPICAL ACCUMULATOR - UNLOADING VALVE CIRCUIT

to tank from the control valve. Again, the pump is protected by an overload relief valve.

The open loop system is by far and large the most practical and the most used for driving fish-boat machinery, since it is very adaptable to driving a number of different devices.

(a) **Open centre, series circuit.** The open loop system can be further divided into two types, the first of which is the *open centre, series circuit* (Figure 4). The pump circulates oil continually through any number of control valves, all piped up in series. The pressure in the system is held to a minimum, being only that required to circulate the oil through the piping and valves. When a control valve is shifted, oil is directed to the motor or cylinder. The pressure in the system is dependent upon the load on the motor or cylinder. This is a constant volume, variable pressure system.

(b) **Closed centre, parallel circuit.** Figure 5 illustrates the *closed centre, parallel circuit.* Here the pump maintains a constant pressure in a header. Any number of valves are connected in parallel off the pressure header. The flow is blocked when the valve is in neutral. When the valve is shifted, oil at a constant pressure is directed to the motor or cylinder. A pressure compensated flow control valve is usually required ahead of each device to control the amount of oil that can be delivered to the motor or cylinder in order to control the speed with which the device is actuated. The flow of oil in the header is dependent on the load. This is a constant pressure, variable volume system.

This type of system generates a good deal of heat when a device is actuated under very little load. For instance, let us assume that the motor shown is operating a winch being run under no load. Assume that the system pressure is 1,000 psig (pounds per square inch gauge) and the flow control valve is set for 30 gallons per minute. Allow 100 psi to idle the motor, then 1,000 psi minus 100 psi times 30 gallons—or approximately 16 horse-power (see Figure 1)—will be converted into heat as the oil is throttled through the flow control valve. Closed centre systems invariably require heat exchangers to control the oil temperature.

The main advantage of a closed centre system is the ability to power a number of devices with widely differing oil volume requirements. The disadvantages include excessive heating, as described above, and the necessity for either a pressure compensated, variable volume pump to maintain the pressure in the header or a system of accumulators and unloading valve to maintain the pressure in the header. Figure 6 illustrates a typical accumulator-unloading valve system. Here the large pump pressurises the circuit and the accumulator (or accumulators). An accumulator is a container in which the hydraulic oil is stored under pressure by compressing a gas or spring. When a preselected pressure is reached, the pressure in the pilot line opens the unloading valve and the discharge from the large pump is bypassed directly back to the reservoir. The small pump maintains the pressure in the system and makes up for any leakage through the control valves. The excess flow from the small pump discharges back to tank over the relief valve. Since only a small flow at high pressure is going across the relief valve the horse-power lost, or heat generated, is kept to a minimum. The large pump is operating under no pressure and the system horse-power is kept to a minimum when at idle.

Henceforth all circuits discussed will be of the *open loop system, open centre, series type circuit* unless specifically defined as a *closed centre system.*

4. ADVANTAGES

The principal advantages of medium pressure hydraulic power, particularly for fishing vessels, are:

4·1 Size

Hydraulic motors are extremely compact in size and light in weight for horse-power delivered. As an example, 440-volt, three-phase, 60-cycle electric motors rated between 1,200 and 1,800 rpm weigh between 20 and 30 pounds per horse-power in the range between 10 and 100 horse-power. High speed diesel engines (1,800 rpm) also fall in this range of 20 to 30 pounds per horse-power. Hydraulic pumps and motors such as are being discussed in this paper weigh between one and two pounds per horse-power. These are 1,500 to 2,000 psi, 1,800 rpm motors of between 10 and 70 horse-power.

This small size and light weight makes possible the application of power wherever it is required and permits the development of such devices as the power block, boom mounted winches, pot line haulers, etc. Countless devices undreamed of today are feasible with such light weight small prime movers.

As with all rotating machinery, for a given horse-power, size and weight varies inversely as the function of the rotational speed, or, stated more simply, the faster the motor or pump rotates and the higher the pressure, the greater the horse-power transmitted for an equal size and weight.

4·2 Reliability and performance

Hydraulic pumps, motors and control valves have all the major working parts fully encased and working in an inhibited lubricant, thus providing extremely long life and reliability. Certain common sense safeguards must be observed for the protection and long life of the components. **The most important and critical of these is the necessity for maintaining clean oil at all times.** More damage can be done to the finely machined polished surfaces of the hydraulic components in the first hour of operation after starting up an improperly cleaned system than 4,000 or more hours of proper, clean operation.

Normal production hydraulic equipment can, and often does, operate fully submerged in salt water. Most inexpensive, commercially available, mass-produced components are constructed out of cast iron or steel and hence are extremely susceptible to rust and corrosion on board ship. However, due to the excellent

seals required to contain the oil, we very seldom find any damage inside motors or other components that can be directly attributed to salt water or to the atmosphere in which they are operating. It is common to find, on poorly maintained vessels, what appear to be piles of rusty scrap iron still performing as well as the day they were installed.

It is extremely difficult to give concrete appraisals of the life of hydraulic components. The service, or duty cycle, is always intermittent on a fishing vessel and most devices, even though they may run many hours a day, are only operating at maximum capacity for short periods of time. Most of the relatively inexpensive mass-produced pumps and motors commonly used with fishing gear are designed to operate between 3,000 and 6,000 hours at full load. The more sophisticated piston type motors often have a full load design life of between 7,000 and 15,000 hours.

4·3 Controls

Perhaps of even greater importance to the fishermen is the wide degree of control available with hydraulic systems. Stepless speed control from stop to full speed with full torque is acknowledged as one of the prime advantages. Properly designed control valves that have good metering or throttling characteristics—that is, the ability to divert differing amounts of oil to the actuator and bypass the remainder—give this precise control of speed. A great variety of spool types and shapes and valve configurations afford the designer and operator a wide choice of performance, function and cost. For instance, $\frac{3}{4}$-inch control valves suitable for 20 to 25 horse-power vary in price from $20 to over $100, depending on style and function.

By controlling the maximum pressure in a system, relief valves effectively limit the maximum torque or force than can be developed. In a winch circuit the relief valve can absorb sudden loads placed on the gear due to the ship's rolling or heaving, thus protecting the winch and the cables. Winches or other hauling devices can be set to either exert a constant force that will pay in when the load is reduced, or pay out when excessive loads are encountered. Electric motors are capable of up to three times the normal torque and diesel engine drives will produce increasing torque until the engine is stalled or slowed down. Neither can be properly controlled on a fishing vessel.

This ability to exert a constant force is particularly advantageous to net and pot haulers where excessive loads suddenly applied due to the ship's motions could easily cause the failure of gear or the loss of the net or pot.

Other control valves useful in certain applications include:

(a) **Pressure reducing valve** — Maintains a constant reduced pressure downstream from the valve regardless of the upstream pressure. These valves are used primarily for control circuits or for control of torque or cylinder force where it is not desirable to use a relief valve.

(b) **Pressure compensated flow control valve** — maintains constant flow (within approximately three to ten per cent regulation depending upon the valve) downstream regardless of fluctuations in pressure upstream. These valves are used in the closed centre parallel type of circuit to control the maximum amount of oil that can be delivered to a motor or cylinder in order to control the speed. They are useful as a bypass valve where a fixed quantity of oil is bled out of the system. (Note flow control bypass valve in Figure 22.)

(c) **Needle valves**—Variable orifices provide a restriction for bypass or control purposes where a constant flow is not required. Unlike the *pressure compensated flow control valve*, the needle will pass a quantity of oil proportionate to the pressure.

(d) **Sequence valves** — Normally closed valves that open when a pilot signal reaches a predetermined value. The unloading valve in Figure 6 is an adaptation of a sequence valve.

(e) **Counterbalance valve** — A modification of an externally piloted sequence valve that permits the lowering of a load by a winch or cylinder with full control, or, in other words, to provide "power down" operation. This is a normally closed valve that opens a small amount to permit the oil to throttle through so that an overhauling load on a winch or cylinder does not "run away". Counterbalance valves are necessary in all open loop type winch circuits where the winch is reversible and must lower the load.

5. THE TRANSMISSION OF HYDRAULIC POWER

Hydraulic oil flowing under pressure represents horse-power. Pumps convert rotary mechanical power from electric motors or engines to flowing fluid under pressure. Motors convert the fluid power to rotary mechanical power; cylinders convert the fluid power to linear mechanical power. Figure 1, mentioned earlier, solves the basic equation of horse-power-fluid flow-pressure. The following formulas are useful in analysing fluid power applications of pumps and motors:

$$\text{(a) } T = \frac{D \times P}{6{\cdot}285}$$

$$\text{(b) } n = 231\,\frac{G}{D}$$

$$\text{(c) } HP = \frac{T \times n}{63{,}025}$$

Where: T=Theoretical torque, inch pounds for either a pump or motor.
D=Displacement, cubic inches per revolution.
P=Pressure, pounds per square inch, gauge.
G=Flow, gallons (at 231 cubic inches per gallon) per minute.
n=Theoretical pump or motor speed, revolutions per minute.
HP=Horse-power.

The above formulas are all based on theoretical values. In practice, the efficiency of vane type pumps varies between 75 and 85 per cent. Figure 7 is a typical set

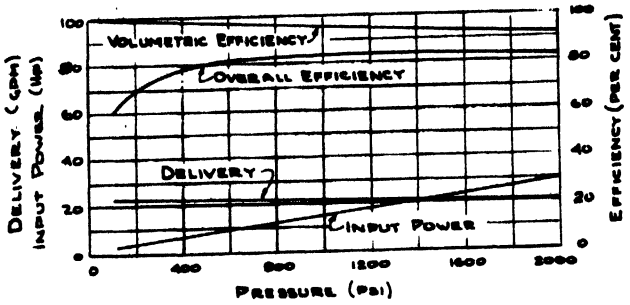


Fig. 7. Typical performance curves for vane pumps.

of performance curves for a vane pump. The efficiency of vane-type motors varies between 75 and 90 per cent. Fig. 8 illustrates typical performance curves for a vane motor.

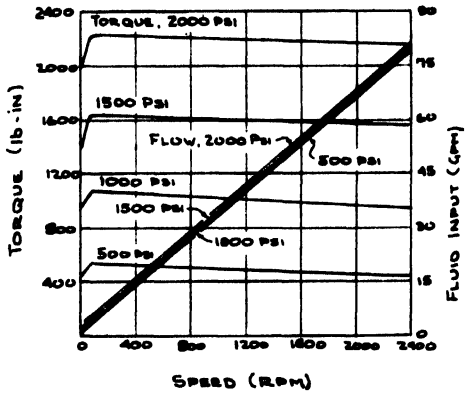


Fig. 8. Typical performance curves for vane motors.

Further inefficiency in the transmission system is caused by pressure drop through the hydraulic line. It is common to assume the overall efficiency between pump input power and motor output power of 50 to 60 per cent to allow for parasitic pressure drop through the entire system. Figure 9 solves the relationship between flow, pipe size and velocity. As a general rule of thumb, velocities in pressure supply lines should not exceed 15 feet per second. Ten feet per second is recommended as a maximum for return lines and two to four feet per second for pump suction lines. Higher velocities may be permitted in large size pipes compared with small size since there is proportionately less oil in contact with the walls of the pipe and tubing. Other factors such as the smoothness of the pipe tubing or hose are to be taken into consideration when sizing the transmission lines. Figure 10, Recommended Pipe Sizes, is a guide for sizing hydraulic lines based upon actual hydraulic pressure loss data of oils with viscosities usually encountered and allows for an increasing total pressure drop with increasing length of total transmission system.

All pressure drops in the system that do not do useful

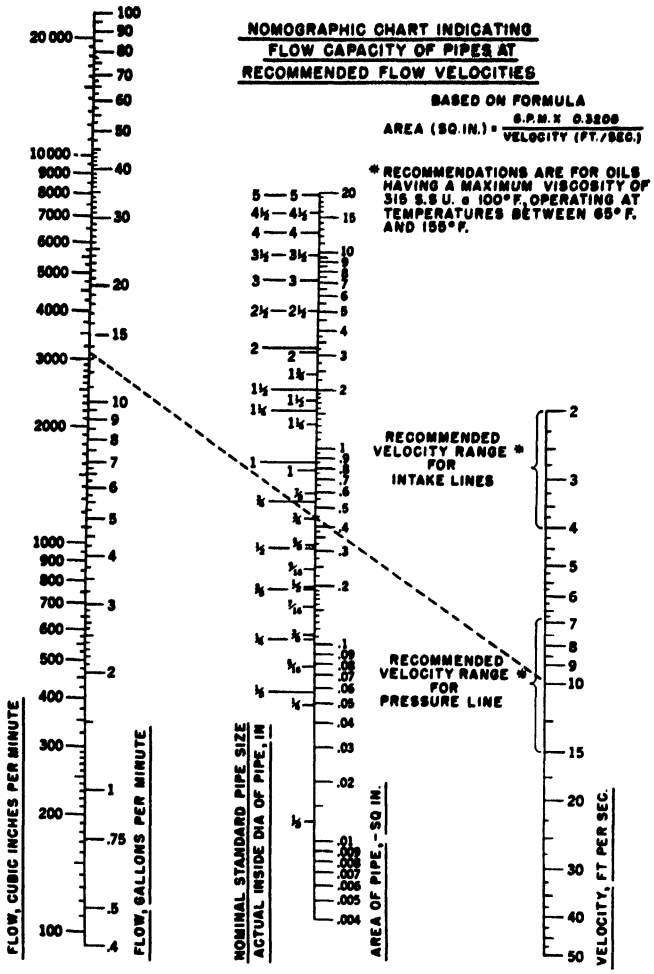


Fig. 9. Flow capacity of pipes.

work must be counted as horse-power lost that shows up as heat. One horse-power is equal to 42·42 BTUs per minute (0·178 calories per second). The heat generated by the pressure drop in the piping of most hydraulic systems is radiated to the surrounding atmosphere at roughly the same rate that it is generated. The hydraulic lines and the reservoir are the two most valuable sources of heat rejection in the system, and are usually sufficient to handle the heat load in a simple, well-designed open centre series circuit with intermittent duty. A workable "rule of thumb" for heat dissipation is to allow two BTUs per hour per square foot per degree Fahrenheit temperature difference.

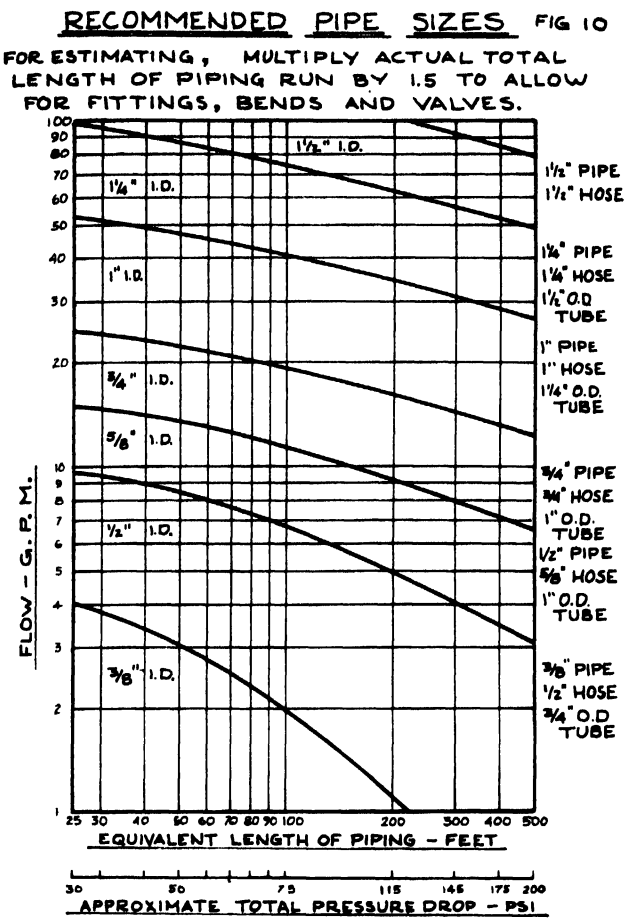
Heat is added to the oil per the formula:

$$q = \frac{G \times \triangle P}{40{\cdot}4}$$

Where:

q=BTU/minute.
G=Gallons per minute.
$\triangle$P=Pressure drop, psig.

Standard weight steel tubing and tube fittings, extra heavy and double extra heavy pipe and various grades



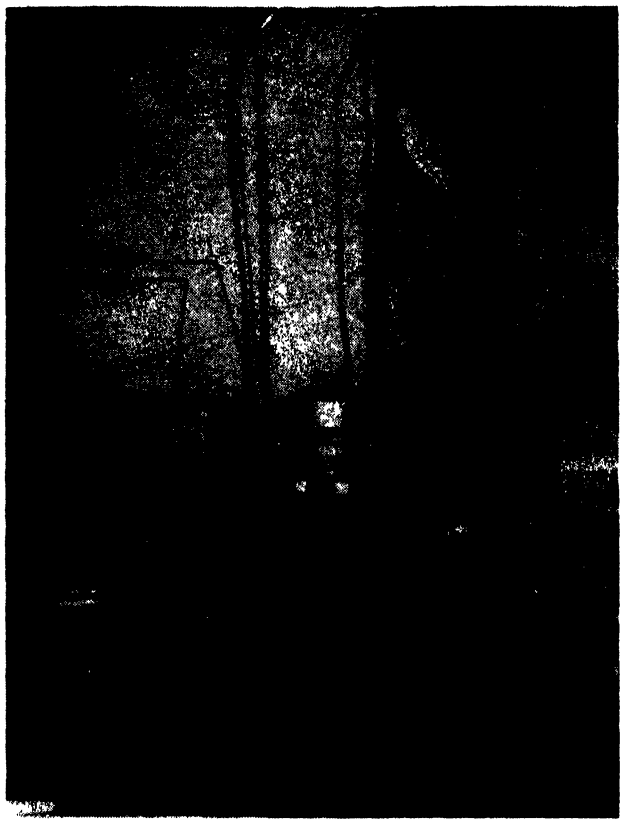


Fig. 11. Typical pump and tank installation. The 7½-hp hydraulic pump is driven from the front power take-off of the main engine on a 46-foot steel fishing vessel.

of neoprene covered wire wound hose and hose fittings are available for transmission systems. Satisfactory installations can use any of these separately or in combinations. Obviously where flexibility is required hose is essential. It is not the purpose of this paper to describe in detail all installation materials. Let it suffice to say they are available and the installer should follow the manufacturer's instructions. (See Appendix 3, Hydraulic System Installation Instructions.)

The front power take-off on the main engine is the most common method of driving hydraulic pumps in small fishing vessels. It is safe to assume that all fishing vessels capable of handling mechanised fishing gear are engine powered and thus have at least one large source of rotating power. These vessels seldom have sufficient auxiliary generating power to drive the hydraulic pumps electrically. Figure 11 shows an hydraulic pump and tank installation on a 46-ft steel combination seiner and crab boat. The diesel engine drives the winch mechanically by the roller chain and sprocket shown in the upper right-hand part of the picture. The hydraulic pump transmission system, which powers the Puretic power block, transmits approximately 7½ horse-power.

On some small fishing vessels such as gillnetters or seine skiffs automotive power steering pumps are directly connected to the engine to drive reels or rollers. These pumps can be operated continuously, just as the power steering pump in an automobile runs continuously when the engine is running, and are designed for high speeds of up to 3,000 or 4,000 rpm. Figure 12 shows this type of pump power pack installed at the front end of a gasoline engine in a 32-ft all-aluminium gillnetter. This pump is equipped with a shaft mounted clutch. Figure

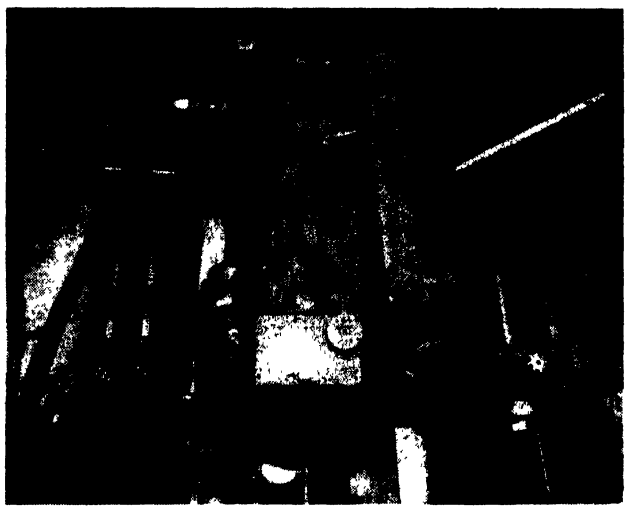


Fig. 12. "Power Pack" installation in small boat. A self-contained combination hydraulic pump and oil reservoir as installed in a 32-foot aluminium gillnetter.

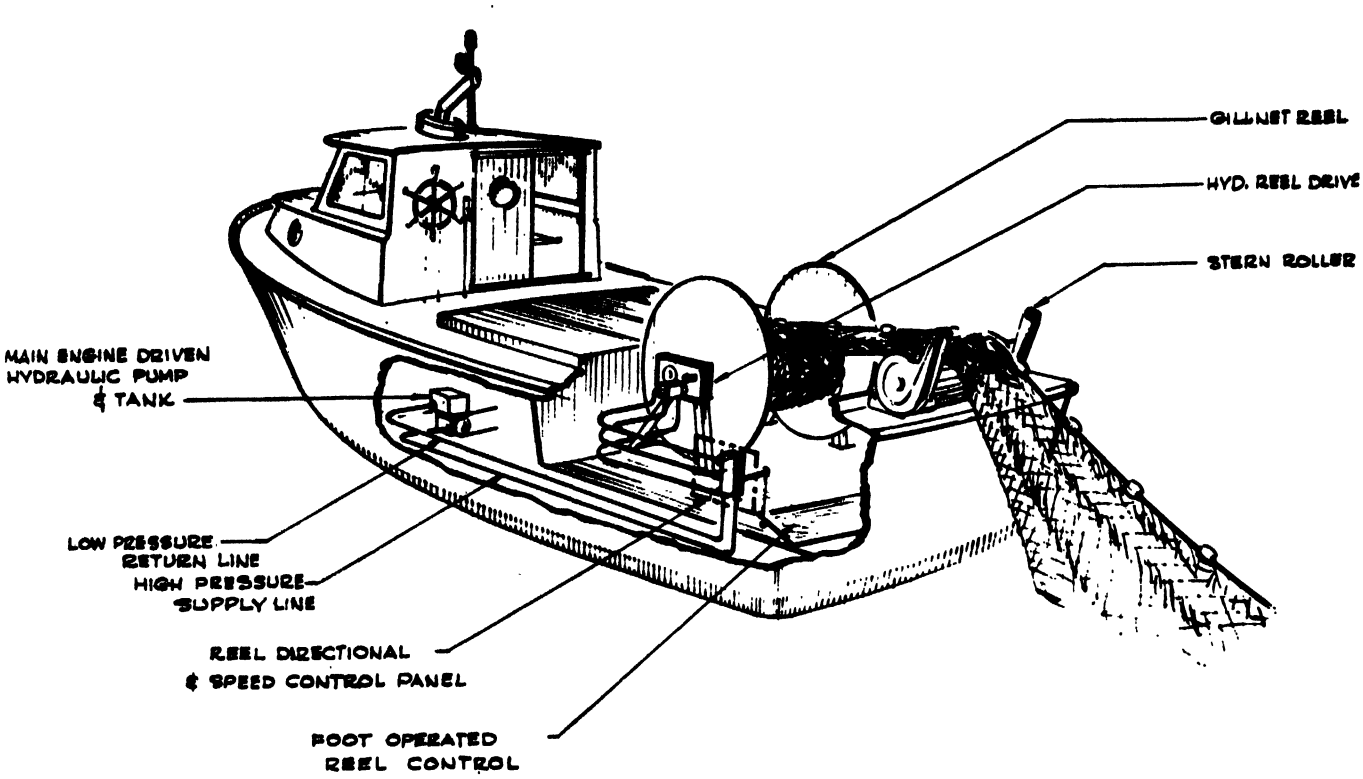


Fig. 13. Hydraulic gillnet reel installation.

13 shows a typical installation of this type of pump driving a stern mounted reel for hauling gillnets.

Larger vessels that have sufficient generating power to drive electric motors often use electro-hydraulic power units. The advantages of the electro-hydraulic power unit include compactness, ease of starting and stopping, ability to be located outside of the engine room, if desired, and a constant speed drive for the pumps. An auxiliary drive, either by electric motor or diesel engine, is of course necessary with a direct reversing engine that is stopped during the fishing operations. Most of the California tuna vessel conversions from bait boats to seiners use electro-hydraulic power units. These vessels all have had sufficient generating capacity to handle the refrigeration and bait circulating pumps. Frequently these electro-hydraulic power units are installed on either the main deck or the raised deck aft near the equipment in order to minimise the amount of piping and protected from the weather by plywood enclosures.

Figure 14 shows a typical power unit. The relief valves are mounted directly on the tank and are piped up to the pump discharges. The electric motor drives a flange mounted double pump. The reservoir contains 50 gallons. This is the same type of power unit that is utilised in Figure 23, Typical Double Pump System for Tuna Vessel.

It is possible to include multiple pumps and motors on a common sub base with the oil tank. Figure 15 illustrates a double electro-hydraulic power unit where each motor drives a flange mounted double pump. Thus there are four separate pump discharges available. Figure 16 illustrates three 40-hp motors mounted on a common sub base with a 250-gallon capacity oil tank and a total of 10 separate pumping cartridges. This power unit operates 12 separate winches on a recently commissioned large fisheries research vessel in the United States.

This power unit was designed to accommodate the owner's requirements for full power operation of any

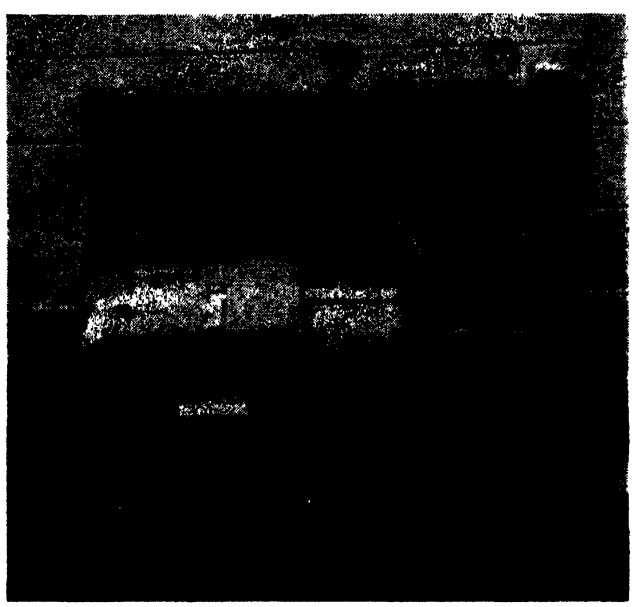


Fig. 14. Electro-hydraulic power unit. A 50-gallon oil reservoir and a 30 hp electric motor driving a double hydraulic pump.

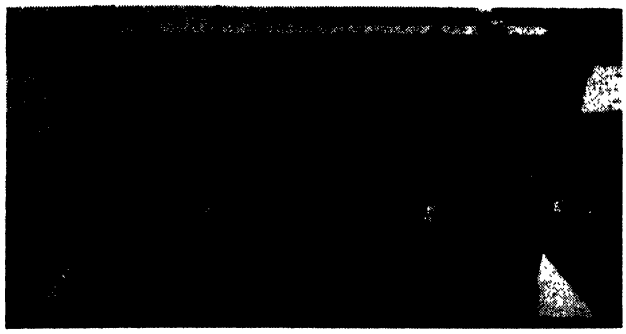


Fig. 15. Double power unit. Two 30-hp electric motors driving double hydraulic pumps connected to a 100-gallon oil reservoir.

The pump would be driven between 1,200 and 1,800 rpm by step-up chain reduction from the front end of the main engine. The pump takes suction from the oil tank and discharges to a control panel that has a pressure gauge, built-in relief valve and by-pass speed control consisting of a needle valve or ball valve so that part of the oil can be bypassed for speed adjustments. The control valve starts, stops and reverses the direction of the hydraulic motor. This type of system is suitable for powering small power blocks, gillnet rollers or reels, pot pullers or other small simple devices. The basic arrangement with the addition of larger pumps and motors, tank and valves is often used for single or multiple drives up to

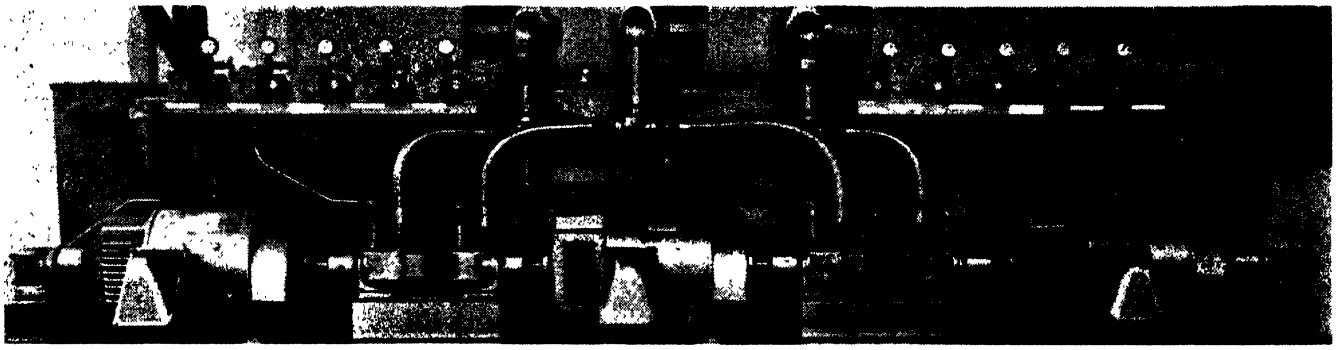


Fig. 16. Triple power unit. Three 40-hp electric motors driving the total of 10 pump cartridges mounted on a common base with a 250-gallon oil reservoir.

pair of winches at any one time. Flange connections on each of the discharge manifold blocks permit emergency cross connections through use of portable hose in the event of a motor or pump failure.

The oil reservoir is a very important item of equipment in the hydraulic circuit. It is common practice to use a reservoir with a capacity in gallons equal to the gallons per minute in the system. Experience has shown that this provides adequate reserve oil and proper operating characteristics. The reservoir functions: (1) to permit the oil to slow down and thus drop the heavy particles being carried along with it; (2) to permit the escapement of entrained air; (3) to serve as a heat sink during peak demands of the system; (4) To serve as a radiator to dissipate the heat in the oil; (5) by being located above the pump suction, to provide a positive suction head to the pump to prevent cavitation. The reservoir should be pickled and cleaned after construction to remove all mill scale, rust and loose weld spatter.

It is always tempting to consider the use of a double-bottom tank in a vessel for a hydraulic oil reservoir. With sea water on one side the tank would make an excellent heat exchanger to keep the oil cool. However, it is impossible to adequately clean a double-bottom tank; consequently at some time or another dirt would be picked up in hydraulic oil that may damage the pumps, motors and valves. Double bottom tanks are not recommended as hydraulic oil reservoirs.

6. SOME HYDRAULIC POWER INSTALLATIONS

6·1 Simple single pump systems

A typical simple hydraulic circuit is shown in Figure 17.

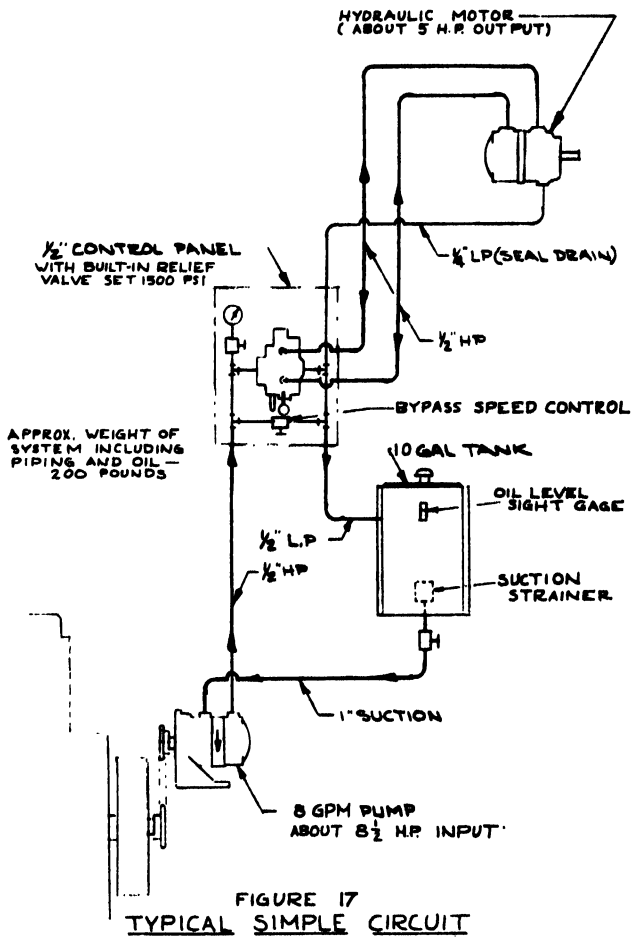


FIGURE 17
TYPICAL SIMPLE CIRCUIT

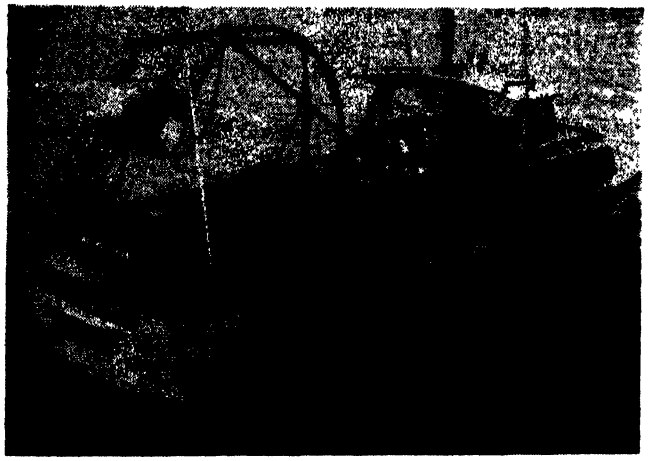


Fig. 18. Gillnetter with hydraulic reel and block. Thirty-two-foot fibre-reinforced plastic gillnetter with hydraulically driven power blockgillnet reel. Only one man operates this vessel.

about 80 horse-power.

Figure 18 shows a fibreglass reinforced plastic gillnetter equipped with a gillnet power block and a gillnet reel. Both the reel and the power block are driven by a circuit similar to that shown in Figure 17; however, only one at a time is used, depending on the season and gear used.

A pair of menhaden seine skiffs are shown in Figure 19. The hydraulic system on each of these skiffs operates

Fig. 19 Hydraulic cranes on purse seine skiffs. Hydraulically operated cranes and power blocks on a pair of menhaden all-aluminium purse seine skiffs fishing off the E. and Gulf Coast of the U.S.

the power block, power block crane, both topping and slewing, and the purse line storage drum. These skiffs average about 36 ft in length by 9 ft to 10 ft in the beam. Hydraulic power is the only practical solution for powering the various items of equipment shown on these boats. It would be impractical to provide an electrical, mechanical or pneumatic power system to power the four different devices.

6·2 Compound pump systems

The rapidly developing Alaskan fishery for King crab has shown fantastic growth in the last few years (Allen, 1963). Here, as in the Dungeness crab fishery along the Washington and Oregon coasts, relatively large vessels with small crews have achieved exceptional productivity through the use of hydraulically powered gear. Figure 20 shows a typical combination fishing vessel rigged for fishing crab. The crab pot hauler is suspended from the end of a special boom. The boom is topped by means of a hydraulic cylinder mounted on the top of the boom. As the cylinder retracts, the boom is raised. The boom is vanged by a separate hydraulic cylinder that mounts on the starboard after corner of the deckhouse. The control valves for the crab block and the boom are mounted just forward of the side trawl winch. (The side winches and the main purse winch on this vessel are driven mechanically from the front power take-off on the main engine. The side winches are used for trawling and not used when fishing crab.) When operating, the fisherman lowers the boom and vangs it over the side. He then retrieves the pot warp and passes it over the pot hauler. The pot hauler pulls the crab pot at approximately 300 feet per minute. As the pot is being raised, the operator will raise the boom with the topping cylinder. When the pot is pulled out of the water and suspended by the crab block, the operator swings the boom inboard with the vanging cylinder, reverses the crab block and drops the pot on the deck.

Figure 21 illustrates an hydraulic system similar to that shown in the photograph, Figure 20. This installation was on a slightly larger boat that also included an hydraulically driven purse winch and anchor winch. Here, a double pump is driven off the front power take-off of the main engine. The discharge of 28 gallons per minute from the large end of the pump is directed through the relief valve and then to a selector valve that selects either the fishing gear circuit or the anchor winch drive circuit. From the selector valve, the 28 gallons per minute passes through the directional control valve for the crab block and then goes to the purse winch. The 12 gallons per minute circuit from the small end of the double pump passes through a relief valve and then to the two control valves in series for the topping and vang cylinders, and then joins the 28 gallons per minute flow from the crab block. This combined flow of 40 gallons per minute is available to the purse winch. The purse winch control consists of a bypass valve which, when closed, forces the oil to circulate through the motor, thus powering the purse winch. To stop the purse winch, the bypass valve is opened. This circuit illustrates the versatility gained by the use of a double pump with two differing oil flows. Here we have the power equivalent of 12 gallons per minute available to the vang cylinders, 28 gallons per minute for the crab block and anchor winch and a total of 40 gallons per minute for the purse winch drive.

Where differing flow requirements are involved the double pump arrangement is by far the most preferable, particularly where the device is to be given fairly severe duty. For very intermittent duty, where a device will be operated for only a short time, we occasionally use a

Fig. 20. Crabpot hauler with active boom. The boom supporting the crabpot hauler is topped and vanged by use of hydraulic cylinders on this combination crab boat and trawler.

single pump and a bypass flow control. Such a system is shown in Figure 22—a typical fishing vessel suitable for purse seining (as shown) or for stern trawling. The main winch is mechanically driven through chain, sprockets and shafting from the front power take-off on the main engine. An hydraulic system is installed primarily to drive the power block. This particular system is set up for 28 gallons per minute to the power block. After the hydraulic oil passes through the power block control valve, part of the oil is bypassed to tank through the flow control valve. The flow control valve is set for approximately 12 gallons per minute. This valve is pressure compensated; in other words, regardless of the pressure upstream from the valve, the valve will adjust itself so that it will pass 12 gallons only back to tank. This forces the remainder of 16 gallons to circulate through the topping winch control valve and the anchor winch control valve. Thus the topping winch and the anchor winch have 16 gallons per minute available to them, although the hydraulic pump is delivering 28 gallons per minute. This is called a *flow control bypass circuit* and should only be used where the service is of very light duty. It must be remembered, as described earlier, that any oil that passes over a flow control valve under pressure will create heat. If the oil is subjected to this heat producing operation for too long a time it will become too hot and severe damage may result. If the oil gets too hot, it will damage the seals in the valves, motors and pumps and it may lose its lubricating characteristics, which will cause physical damage to the pumps and motors.

The larger the vessel and the greater the number of devices powered, the more complex becomes the hydraulic system. A power system for a tuna seiner conversion is illustrated in Figure 23. Here a single electric motor drives a double pump delivering 35 and 16 gallons per minute. The total horse-power input required by this double pump if both are delivering oil at rated speed at relief valve setting would be approximately 50 horse-power; however, when in actual use this condition would not normally be encountered, therefore a 30 horse-power motor can be used to drive the pump. This will provide

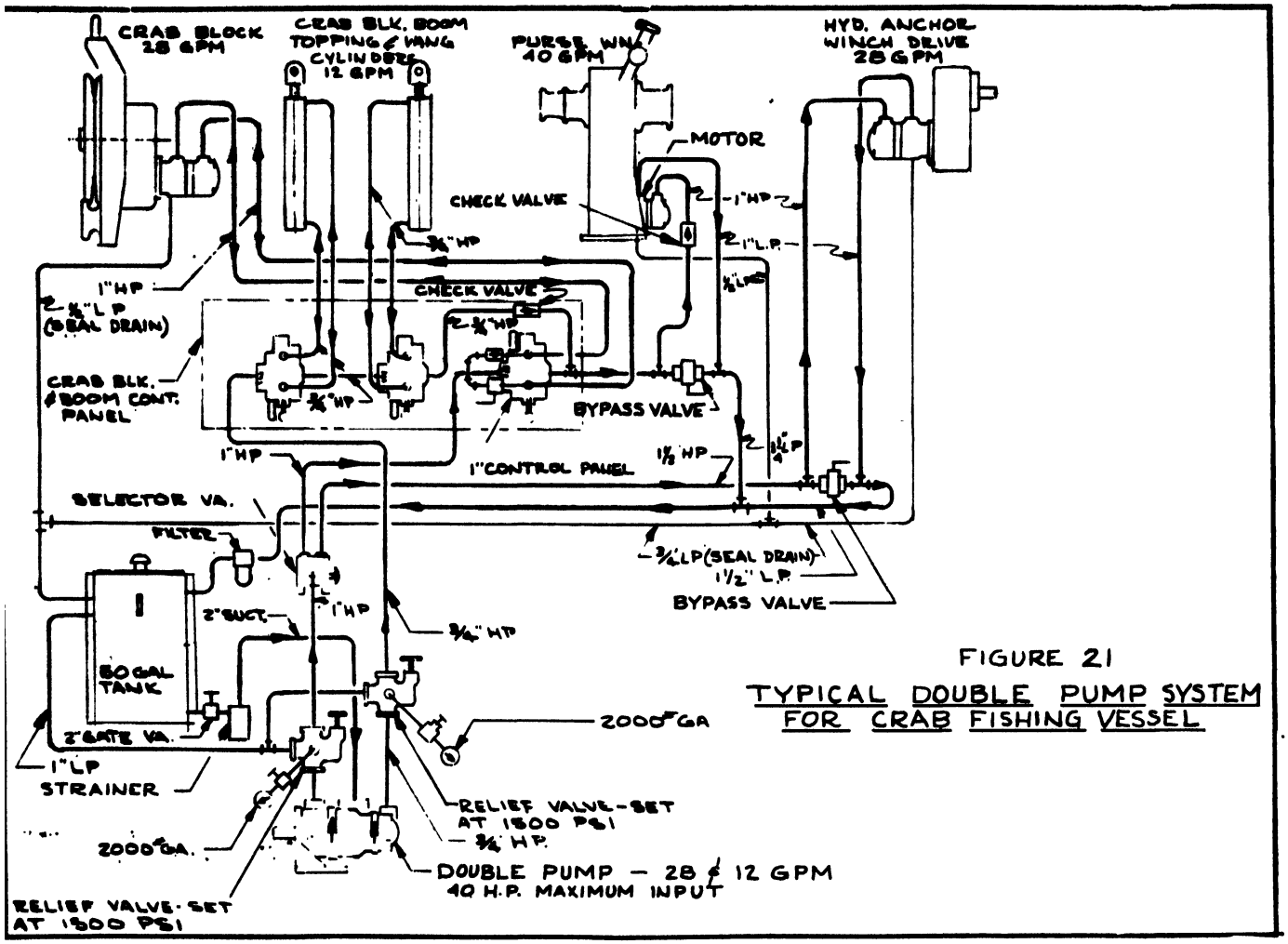


FIGURE 21
TYPICAL DOUBLE PUMP SYSTEM FOR CRAB FISHING VESSEL

sufficient power for the power block, which is operated a greater length of time than the other winches. In this circuit we see that each section of the double pump has one particular service and the discharges are not combined. The larger section drives the power block and the smaller section drives the vanging and topping winches, the boom winch and the cork line winch.

A good deal of progress in the application of hydraulics to fishing gear has developed among the purse seiners. Before the advent of the power block many purse seiners converted their turntables to purse seine reels. The reels were mounted on the existing turntable rollers and powered hydraulically. Figure 24 illustrates a typical purse seine reel mounted on such a conversion. The seine is set with the reel in the position shown. To retrieve the net the reel is turned approximately 90 degrees so it faces over the side of the vessel. Pursing is done on the forward section of the net only, and the after section of the net is hauled in on the drum at the same time the net is being pursed. An hydraulically powered fairlead runs back and forth over a track and guides the net on to the drum so that it may be spooled evenly. The rotation of the turntable, the powering of the drum, and the powering of the level wind are all done hydraulically. This is one of the most efficient methods yet devised for the handling of purse seines; the fewest number of men can set and retrieve the net. Today only a very few new boats are constructed with the purse seine reel due primarily to its high cost and weight.

6·3 Remote controls on a purse seiner

It was mentioned in an earlier section of this paper that one of the benefits from a hydraulic transmission was the ability to provide remote control of winches and other gear. Figure 25 shows a six-drum purse seine winch and the winch control console. The six drums are: (1) main purse line; (2) forward purse line; (3) tow line; (4) auxiliary back drum for the heavy lift; (5) auxiliary back drum for strapping and (6) auxiliary back drum for either choking or brailing. All drums have hydraulically actuated brakes and clutches that are controlled remotely from the control console. The brakes, clutches and all gearing for this winch are totally enclosed in a double wall case and operate in oil, thus providing full splash lubrication at all times and protecting the machined surfaces from the weather. The control valves are

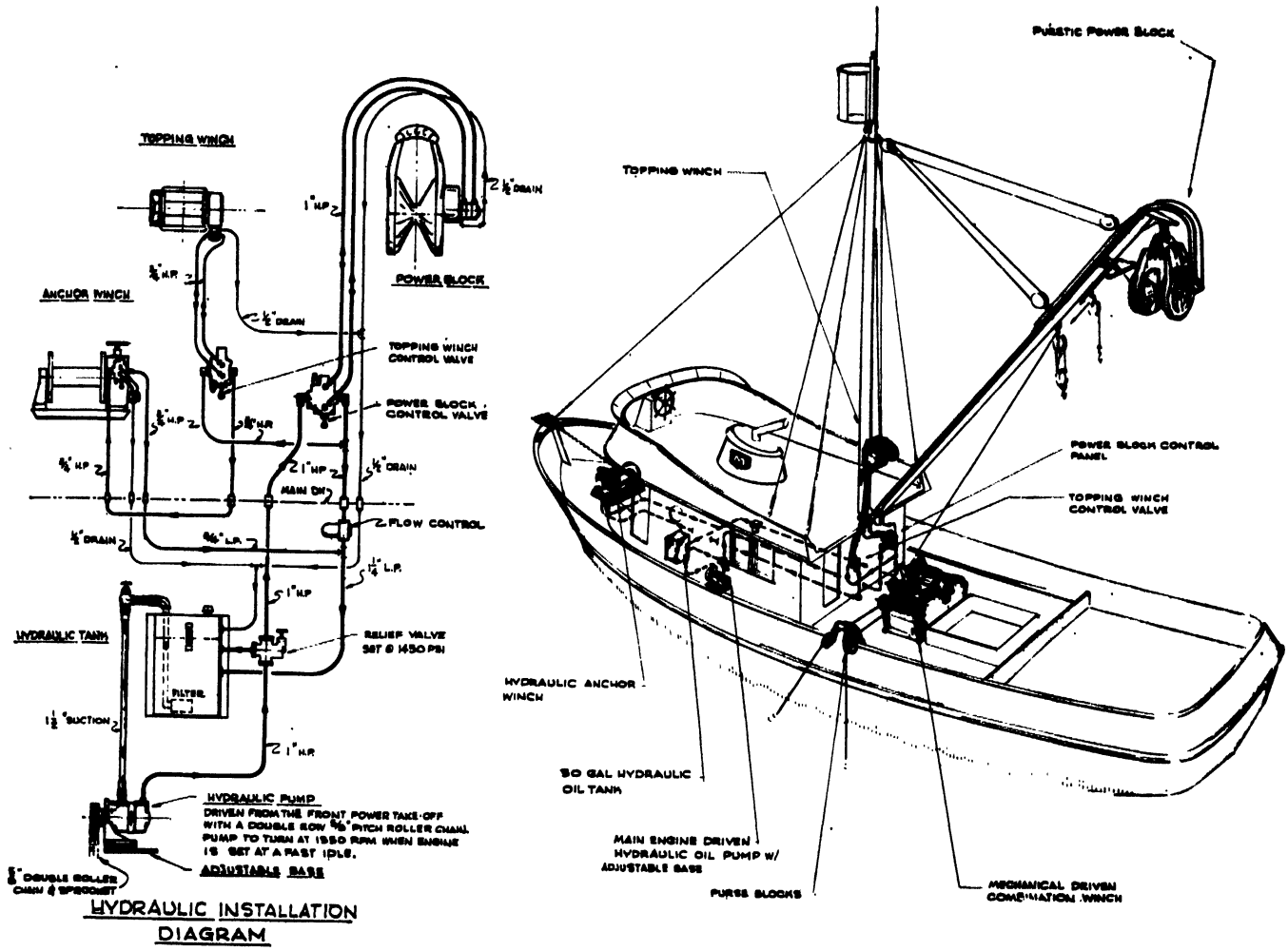


Fig. 22. Typical deck machinery and piping layout.

designed so that the operator can feel the load: in other words, as he applies hydraulic pressure to the brake or clutch by manipulating the valve the handle provides increased resistance with increasing load. The winch drive incorporates two motors that can be operated either in series or in parallel. Both motors are permanently geared (not clutched) to the winch drive. When the hydraulic oil flows through both motors in series (see Figure 28) the winch is driven at the maximum speed and only one motor does useful work. When the flow is divided so that half flows through each motor the speed of the winch is cut in half and the torque is doubled since each motor has full pressure available. All controls for the drive, as well as the brake and clutches for the drums, are located in the control console. Figure 26 shows this winch and control console installed on a recent tuna vessel conversion. A separate control console mounted to the right of the winch console controls the power block, vang winches and topping winch. The hydraulic topping winch can be seen mounted on the mast to the left of the control console.

Figure 27 represents typical line pull requirements encountered by a purse seine winch of this type. Data for the curve are based upon research by Ishii and Konagaya (1961) and modified by our observations of hydraulic winch drives on tuna vessels. It will be noted that the series-parallel drive provides high line speed when the line pull is low at the beginning of the pursing operation. As the net is pursed up the line pull increases until the winch stalls. At this point (or slightly before, depending upon the operator) the winch is shifted into parallel drive which doubles the line pull at one-half the speed. As the rings are picked out of the water and are pulled up the side of the boat to the purse davit, the operator has full control of speed and can stop the winch and hold the rings with complete control and maximum safety. This winch drive provides approximately 35 horse-power which, although not large, is applied in the proper speeds and pull to do the most efficient job.

Figure 28 illustrates a typical series-parallel winch drive circuit similar to that utilised on the winch shown in Figure 25. Here the winch is driven by two pumps, the large pump providing two-thirds the total flow and the small pump providing one-third the total flow. In practice, each of these pumps could be expected to

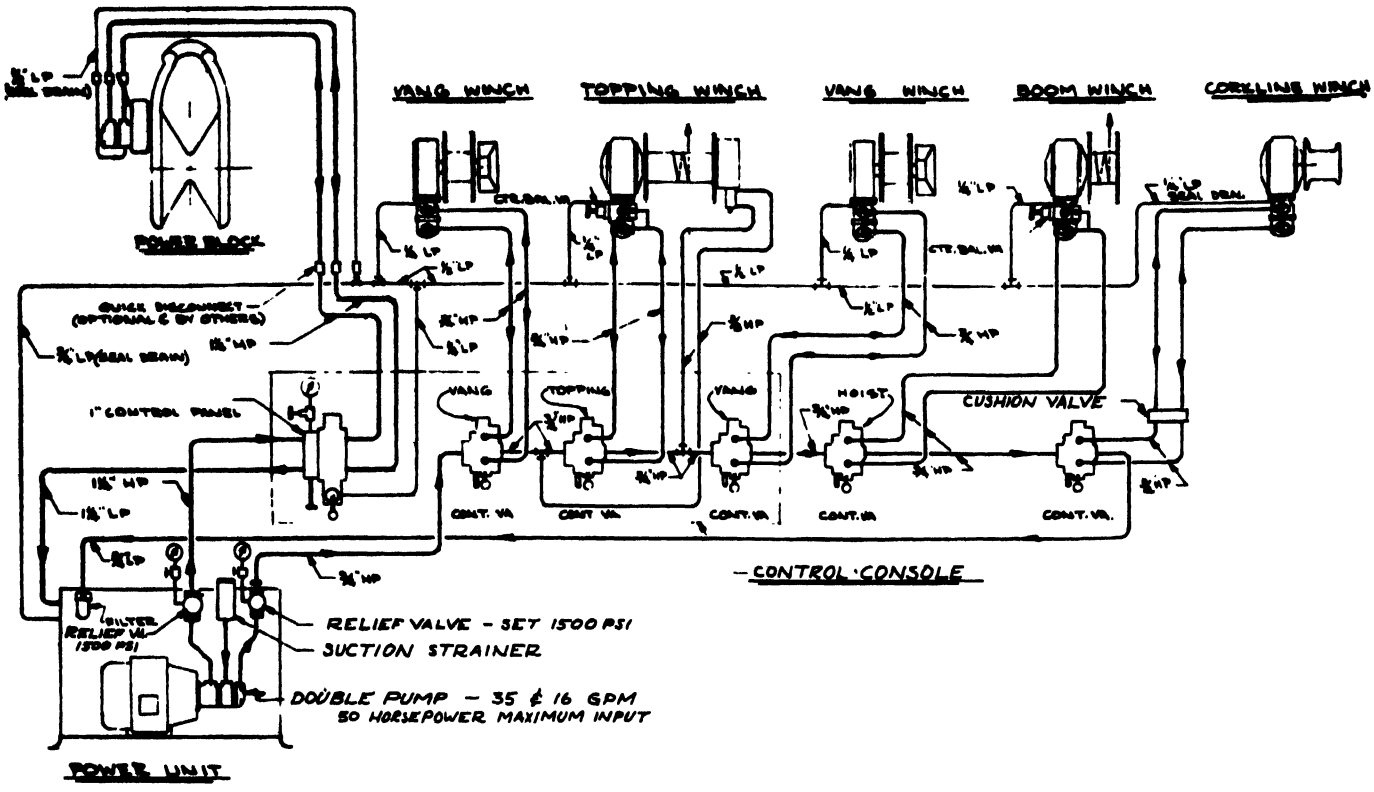
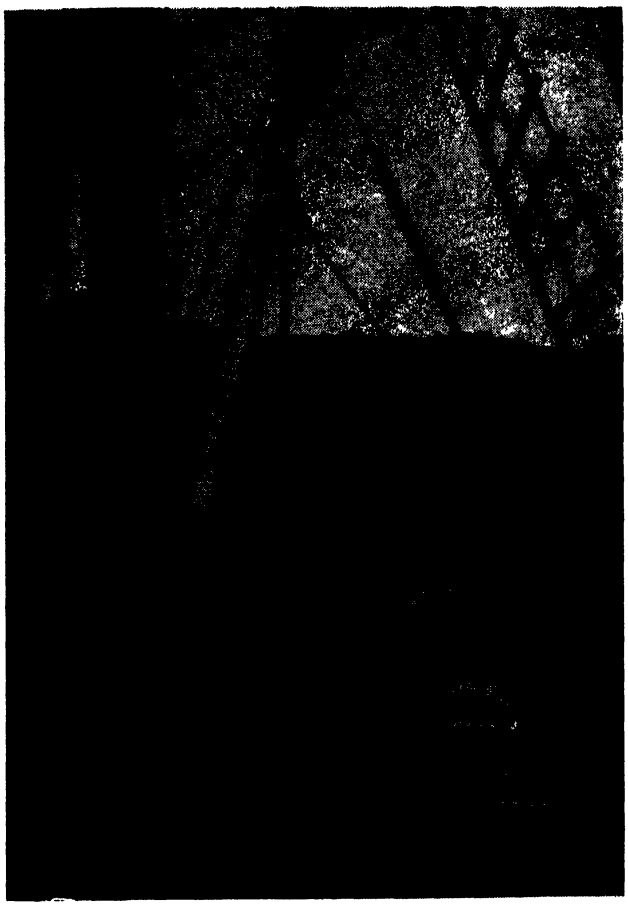


Fig. 23. Typical double pump system for tuna vessel.

Fig. 24. Salmon purse seine reel. The salmon purse seine is shown wound on an hydraulically powered reel. The reel is mounted on an hydraulically powered turntable. An hydraulically powered fairlead roller (not shown) spools the net evenly.

Fig. 25. Hydraulic seine winch. A modern tuna seine winch with hydraulically operated brakes and clutches and drive. The winch is controlled entirely from a remote location by the control panel shown.

power other items of equipment such as power block, topping winch, etc., on the vessel, as well as the winch drive. The pilot-operated, remote-controlled relief valves, when vented (that is, an internal compartment in the valve is vented to tank, thus opening the valve fully) open to allow oil to bypass directly from the high side of the circuit to the tank return line. These valves are controlled independently by the small, manually operated bypass valves (note the small black knobs extending through the top of the control console in Figure 25). This arrangement permits bypassing either the large or the small pump to provide one-third speed, two-thirds speed or full speed in either torque range. The manually operated series-parallel selector valve directs the oil flow so that the oil must pass through the two motors (series), or is divided and half flows to each motor (parallel). The remote relief valve provides partial venting of the two pilot operated, remote-controlled relief valves, thus effecting fine speed adjustment. The "panic button" controls the starting and stopping of the winch. A second optional winch stop valve can be located on or near the winch. This "panic button"



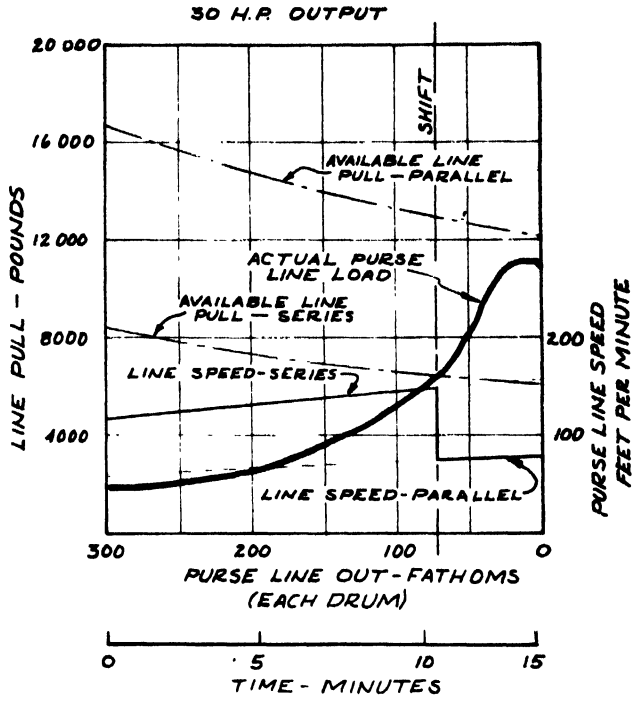
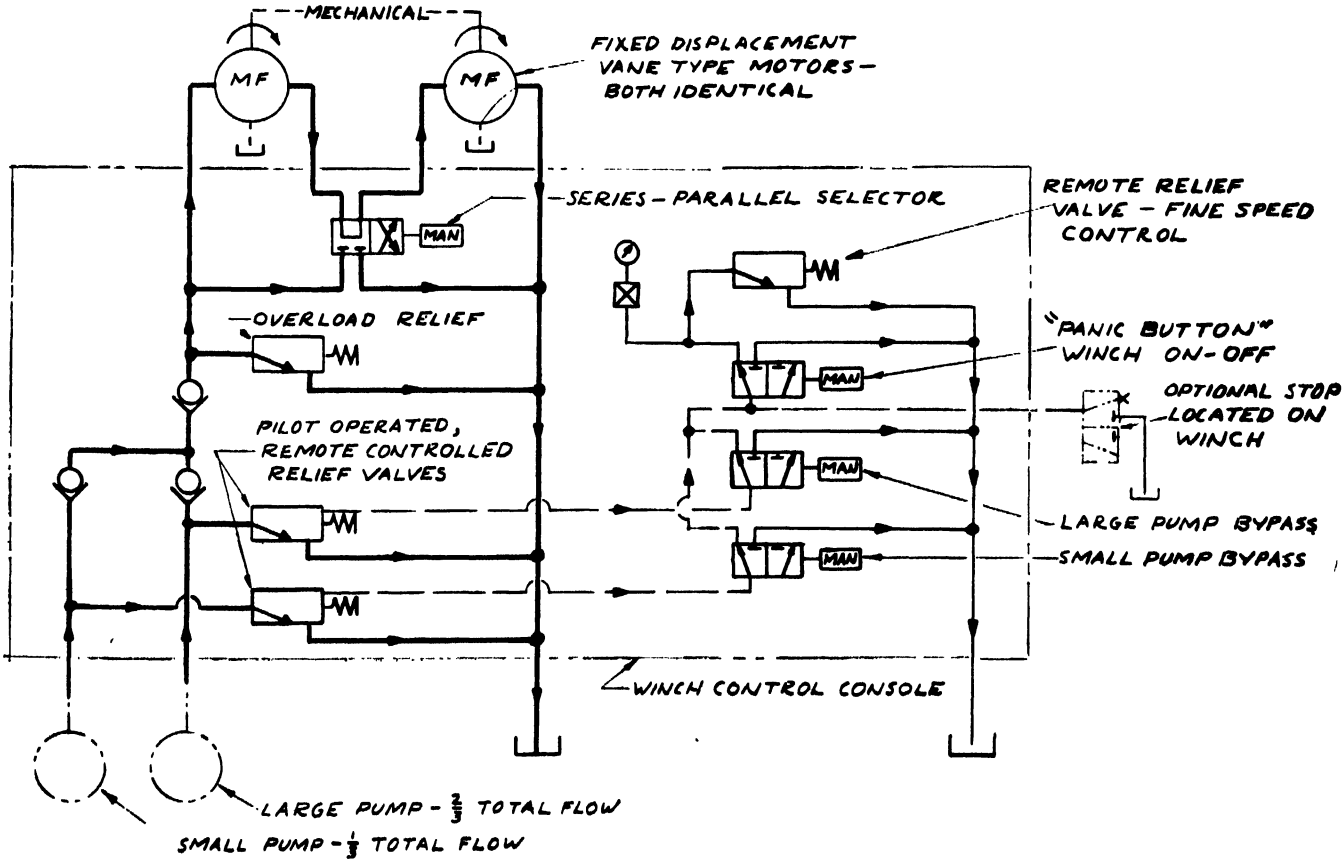


Fig. 26. (left) Tuna seine winch installation. The seine winch, its control console and the power block and vang and topping winch control console are shown installed on a recently converted European tuna vessel.

Fig. 27. (above) Typical performance curves for series parallel seine winch hydraulic drive.

Fig. 28. (below) Series-parallel winch drive circuit.



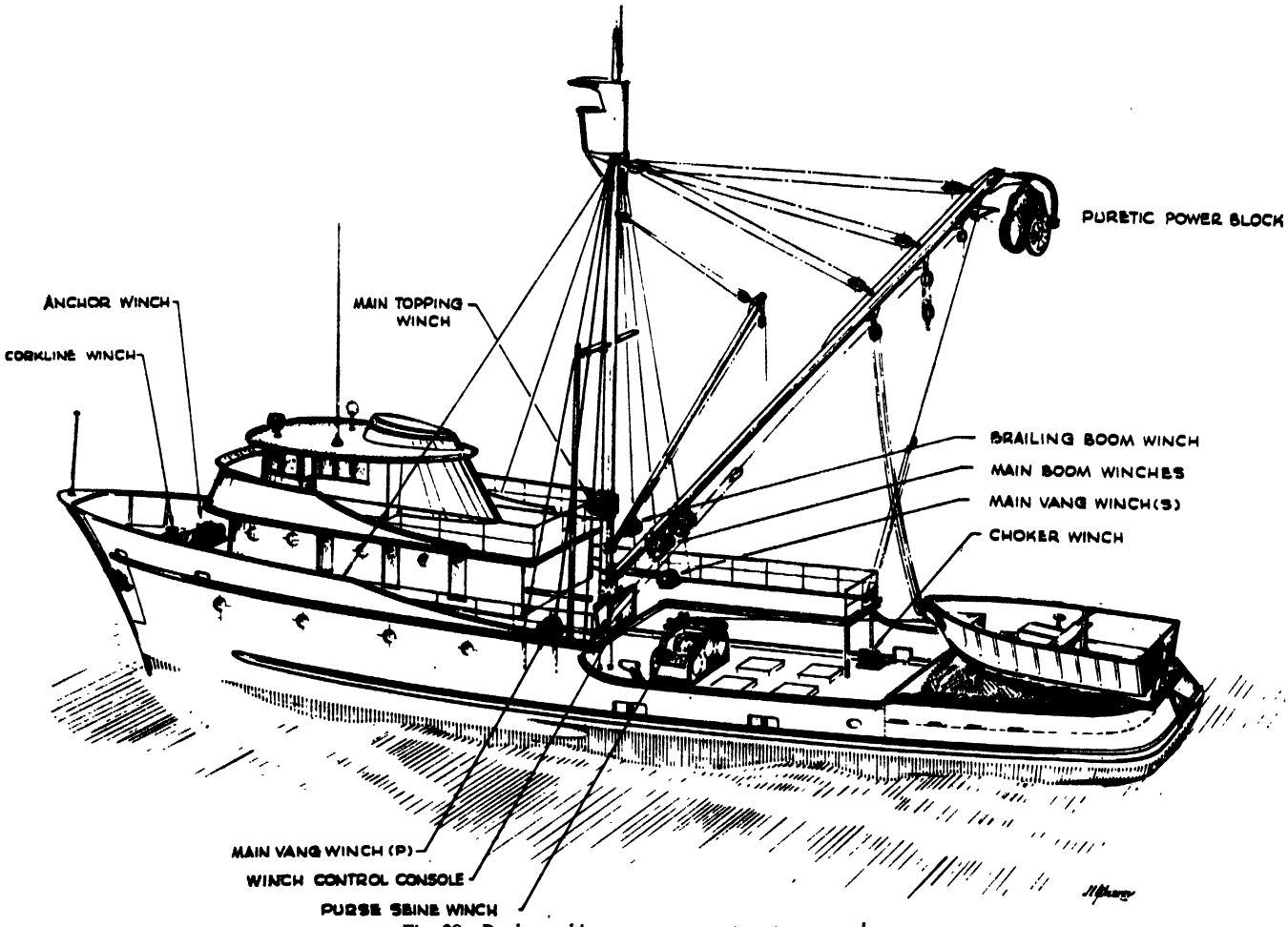


Fig. 29. Deck machinery arrangement on tuna vessel.

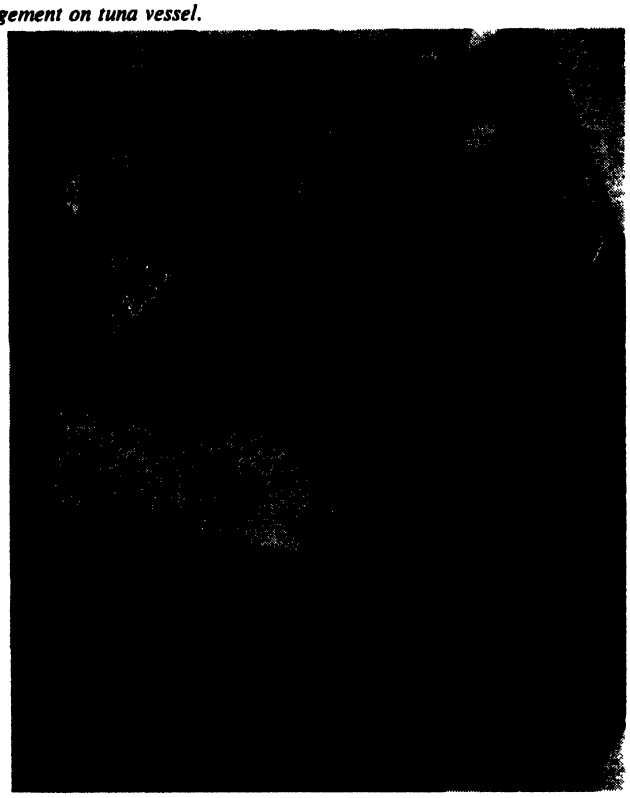


Fig. 31. (right) Hydraulic winches and reels on stern trawler. Two side trawl winches each driven by a separate hydraulic pump, handle the trawl warps. The net reel is powered off one of the trawl winch pumps.

is one of the most valuable features of this type of hydraulic drive. It permits the operator to stop the winch immediately by merely hitting the button with his hand, thus venting both pilot-operated remote-controlled relief valves, which react very rapidly to bypass the oil, stopping the winch. Recently many winch drives have been installed using a diesel engine and a torque converter, a very effective and powerful drive that provides usually both more line speed at the beginning of pursing and more available line pull at a much reduced speed at the end of pursing. However, due to the nature of the torque converter the speed varies with the load as well as the speed of the diesel engine prime mover. The main disadvantage as far as the fishermen are concerned is the inability to stop the winch immediately in the event of a crisis.

A modern, fully equipped tuna purse seiner is illustrated in Figure 29. All major items of powered fishing gear are shown. All winches except the cork line winch and the anchor winch, which have controls locally mounted, are remotely operated from the winch control console mounted on the raised deck. Here the operator

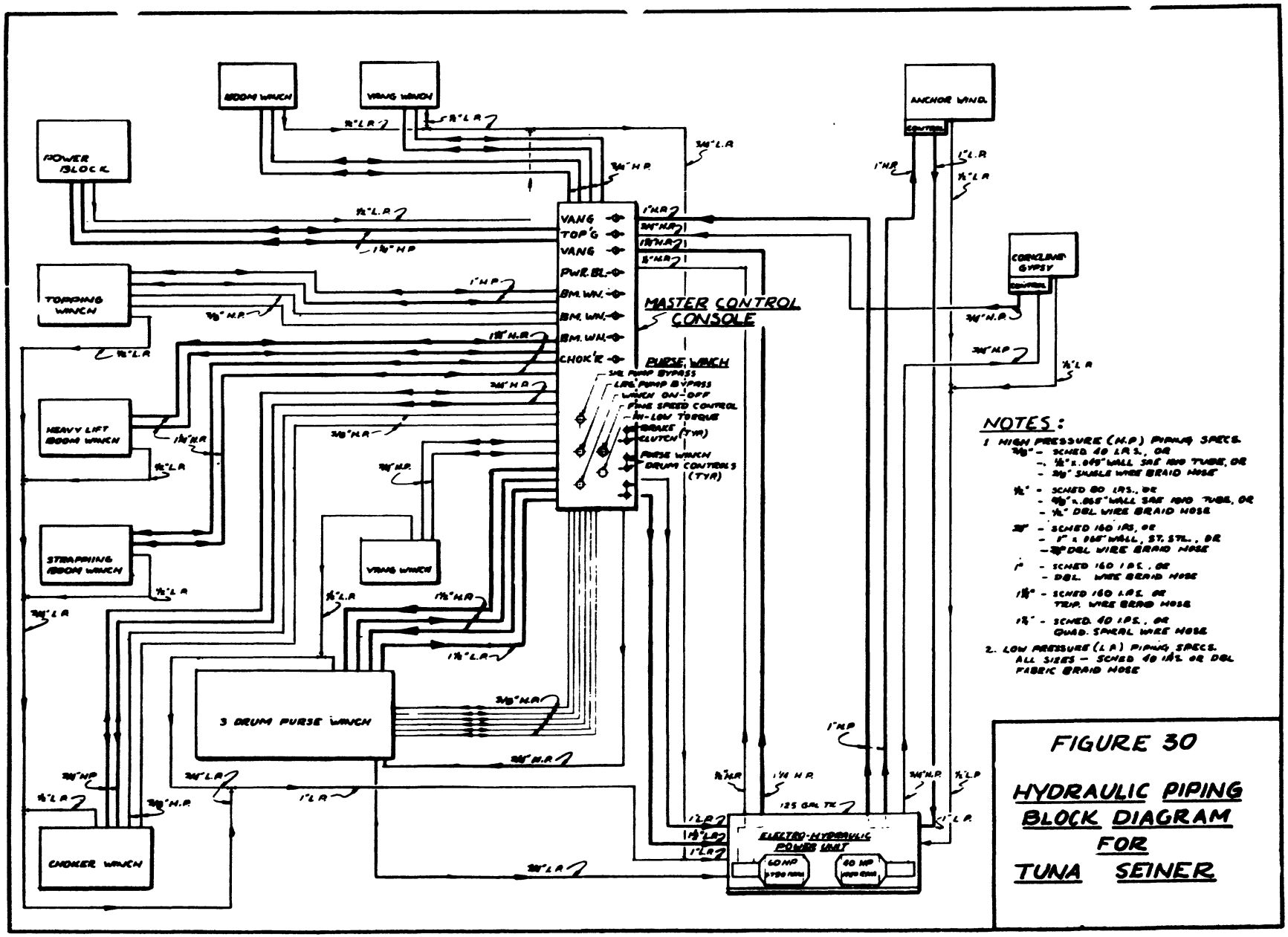


FIGURE 30

HYDRAULIC PIPING BLOCK DIAGRAM FOR TUNA SEINER

has an unobstructed view of the whole fishing operation and has fingertip control of all powered winches. His hydraulically actuated brakes on the main purse winch give him complete control of the purse line when making a set. He has complete control of lifting the rings or skiff, strapping, choking and brailing, thus freeing the rest of the crew to handle the net and the lines.

All winches are powered by a central electro-hydraulic power unit. The circuit is illustrated in Figure 30 and consists of a 125-gallon oil tank and two double pumps driven by 60 and 40 horse-power electric motors. All shipyard-installed piping is illustrated as connections between the blocks representing the various items of equipment. Unquestionably a great deal of piping is involved for such a system; hence the initial installation is expensive. However, once the system is installed and properly set it can be expected to operate with a very minimum of maintenance and expensive down-time.

6·4 Stern trawler installation

Although most of the discussion heretofore has concerned either small vessels or purse seiners, hydraulically powered equipment plays comparable roles on trawlers, longliners and other types of vessels. Figure 31 shows the installation of gear on a typical stern trawler as used in the Pacific Northwest. This vessel is approximately 65 ft in length. The trawlwarps are carried on independently powered side trawl winches. Each winch has its own pump and motor—driven from the front end of the main engine. The reel for retrieving and stowing the trawl is powered by one of the pumps. Separate smaller hydraulic pumps power two two-ton winches mounted on the main boom. The control valves for the trawl winches are mounted on each winch. The control valves for the boom mounted winches are located on the back of the deckhouse. Of particular interest are the clear, unobstructed decks, made possible by the use of hydraulic drives.

7. Conclusion

The use of hydraulic transmission systems, pumps and motors is playing an ever-increasing role in the rapidly advancing technology of modern fisheries. Hydraulically powered fishing gear similar in design and operation to that illustrated in this paper is in use in many different fisheries of the world. Approximately 2,500 systems are making fishing easier, safer and more productive. The operation is basically simple and easily understood by the fishermen. The components, nearly all of which are mass-produced, are relatively inexpensive and very reliable. Satisfactory oil for hydraulic service is available wherever there is a major marketing programme for petroleum products. Besides the so-called "hydraulic oils", premium heavy-duty diesel engine motor oil will give perfectly satisfactory service.

Finally, it cannot be too strongly stressed that when hydraulic systems are being installed, the manufacturers' detailed instructions should be followed most closely in order to avoid risk of leaks, dirt and circulation troubles. Such care will be well repaid by trouble-free operation.

Acknowledgments

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(See Important Appendices in following pages)

APPENDIX 1

STANDARD GRAPHICAL SYMBOLS

(from ASA-732.10)

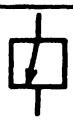
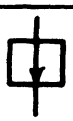
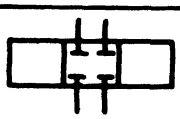
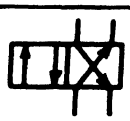
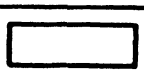
Basic symbols can be combined in any form desired. No attempt is made to show all combinations.

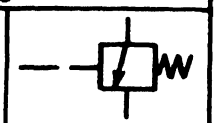
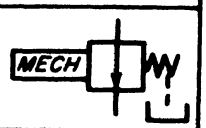
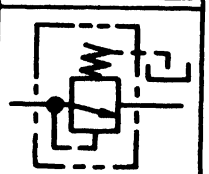
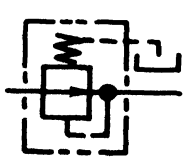
LINES AND LINE FUNCTIONS	
LINE, WORKING	
LINE, PILOT (L>20W)	
LINE, DRAIN (L<5W)	
CONNECTOR (DOT TO BE 5X WIDTH OF LINES)	
LINE, FLEXIBLE	
LINE, JOINING	
LINE, PASSING	
DIRECTON OF FLOW	
LINE TO RESERVOIR ABOVE FLUID LEVEL BELOW FLUID LEVEL	
LINE TO VENTED MANIFOLD	
PLUG OR PLUGGED CONNECTION	
TESTING STATION (GAGE CONNECTION)	
POWER TAKEOFF (HYD.)	
RESTRICTION, FIXED	
RESTRICTION, VARIABLE	

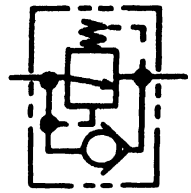
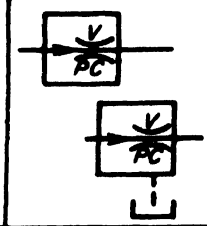
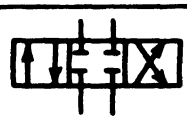
PUMPS	
PUMP, SINGLE, FIXED DISPLACEMENT	PF
PUMP, SINGLE, VARIABLE, DISPLACEMENT	PV

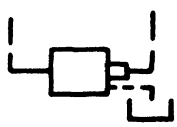
MOTORS AND CYLINDERS	
MOTOR, ROTARY, FIXED DISPLACEMENT	MF
MOTOR, ROTARY, VARIABLE DISPLACEMENT	MV
MOTOR, OSCILLATING	MO
CYLINDER, SINGLE ACTING	
CYINDER, DOUBLE ACTING SINGLE END ROD DOUBLE END ROD	

MISCELLANEOUS UNITS	
ROTATING SHAFT (ARROW IN FRONT OF SHAFT)	
COMPONENT ENCLOSURE	
RESERVOIR	
PRESSURE GAGE	
OTHER * Insert appropriate letter combinations and add appropriate symbols to indicate shafts or connecting flow lines. ACC ACCUMULATOR ELEC MOT ELECTRIC MOTOR ENG ENGINE FLT FILTER FM FLOW METER HE HEAT EXCHANGER INT INTENSIFIER PS PRESSURE SWITCH STR STRAINER TACH TACHOMETER	

VALVES AND BASIC SYMBOLS	
VALVE, CHECK	
VALVE, MANUAL SHUTOFF	
VALVE, MAXIMUM PRESSURE (RELIEF)	
VALVE, BASIC SYMBOL SINGLE FLOW PATH IS MODIFIED.	
VALVE, BASIC SYMBOL MULTIPLE FLOW PATHS ARE CHANGED	
VALVE, SINGLE FLOW PATH, NORMALLY CLOSED	
VALVE, SINGLE FLOW PATH, NORMALLY OPEN	
VALVE, MULTIPLE FLOW PATHS, BLOCKED	
VALVE, MULTIPLE FLOW PATHS, OPEN (ARROWS DENOTE DIRECTION OF FLOW)	
VALVE, SPECIAL (IDENTIFY AND CONNECT ALL LINES)	

VALVE EXAMPLES	
VALVE, RELIEF REMOTELY OPERATED (UNLOADING VALVE)	
VALVE, DECELERATION NORMALLY OPEN	
VALVE, SEQUENCE, DIRECTLY OPERATED	
VALVE, PRESSURE REDUCING	

VALVE EXAMPLES (CONT.)	
VALVE, COUNTERBALANCE WITH INTEGRAL CHECK	
VALVE, FLOW-RATE CONTROL, VARIABLE, PRESSURE COMPENSATED	
VALVE, DIRECTIONAL, 2 POSITION 3 CONNECTION	
VALVE, DIRECTIONAL, 3 POSITION 4 CONNECTION OPEN CENTER	
VALVE, DIRECTIONAL, 3 POSITION 4 CONNECTION CLOSED CENTER	

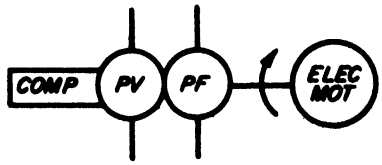
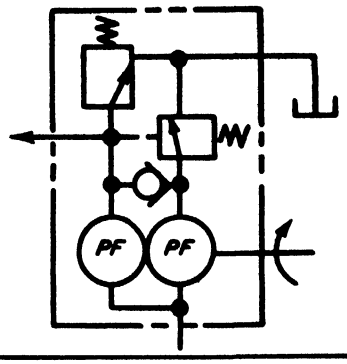
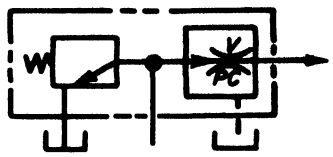
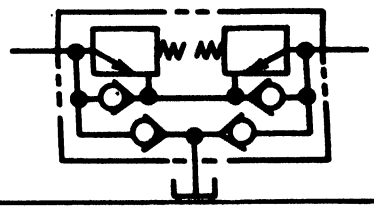
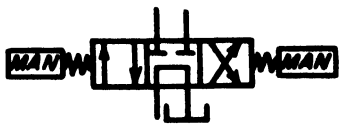
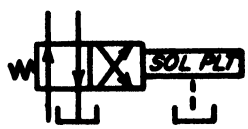
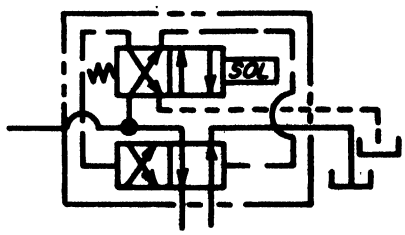
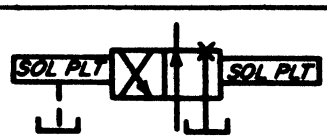
METHODS OF CONTROL	
SPRING	
PILOT OPERATED	
PILOT OPERATED, DIFFERENTIAL AREA	
OTHER	

* Insert appropriate letter combinations and add connecting flow lines.

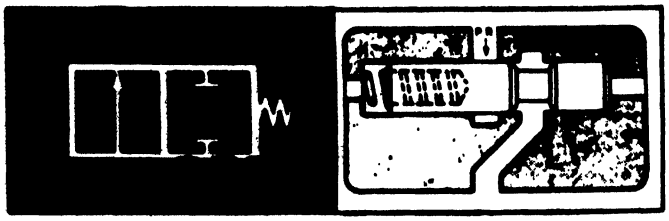
CENT	CENTRIFUGAL
COMP	COMPENSATOR
CYL	CYLINDER
DET	DETENT
ELEC MOT	ELECTRIC MOTOR
HYD MOT	HYDRAULIC MOTOR
MAN	MANUAL
MECH	MECHANICAL
SERV	SERVO
SOL	SOLENOID
SOL PLT	SOLENOID CONTROLLED, PILOT OPERATED
THRM	THERMAL

APPENDIX 1

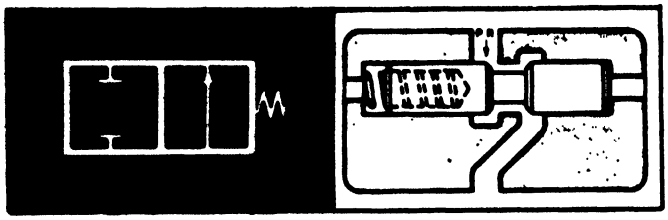
SAMPLE COMPOSITE SYMBOLS

PUMP, DOUBLE, WITH ELECTRIC MOTOR ONE FIXED DISPLACEMENT ONE VARIABLE DISPLACEMENT WITH COMPENSATOR CONTROL	
PUMP, DOUBLE, WITH IN-BUILT CHECK, RELIEF AND UNLOADING VALVES.	
VALVE, PRESSURE COMPENSATED VARIABLE FLOW-RATE CONTROL WITH MAXIMUM PRESSURE CONTROL	
VALVE, RELIEF AND REPLENISHING	
VALVE, 4-WAY, MANUALLY CONTROLLED, SPRING CENTERED. (PORTING AT CENTER IS P TO T WITH CYLINDER PORTS BLOCKED)	
VALVE, 4-WAY SOLENOID CONTROLLED, PILOT OPERATED, SPRING OFFSET SIMPLIFIED SYMBOL COMPOUND SYMBOL	 
VALVE, 4-WAY, SOLENOID CONTROLLED, PILOT OPERATED, NO SPRING (ONE PORT PLUGGED)	

Directional Controls



2-Way, normally closed



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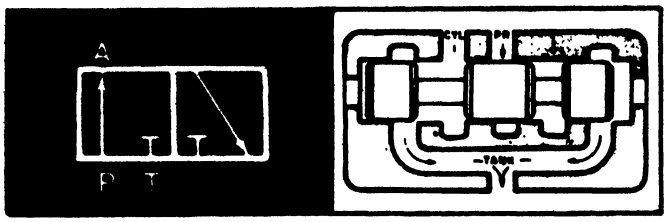
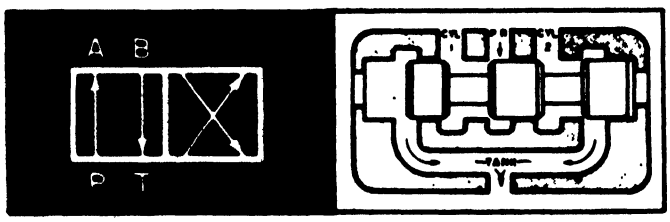
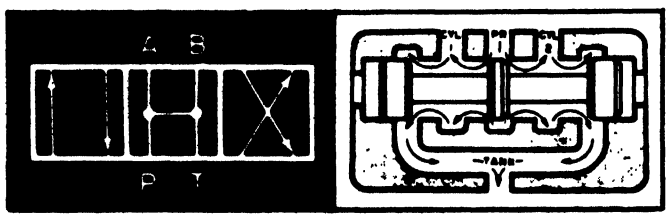


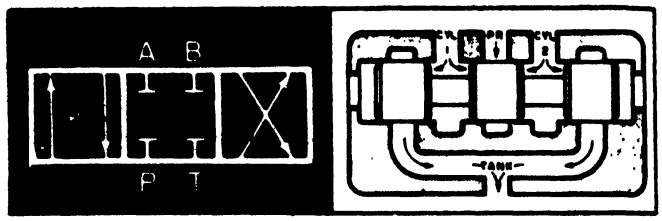
3-Way



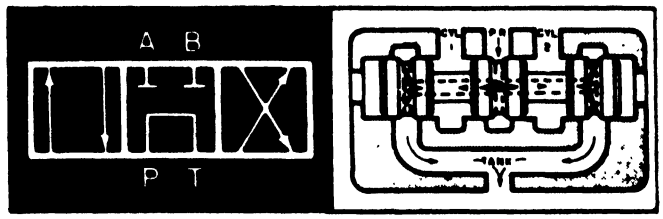
4-Way, 2-position



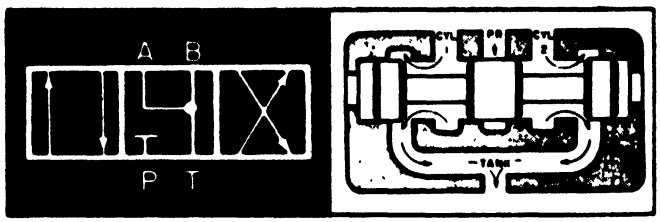
4-Way, 3-position, open-center



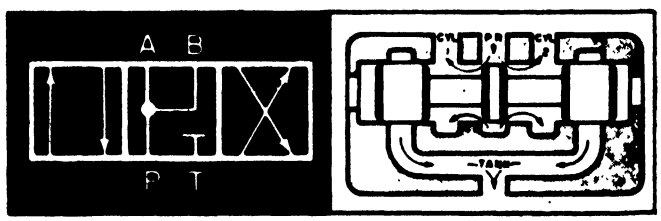
4-Way, 3-position, closed-center



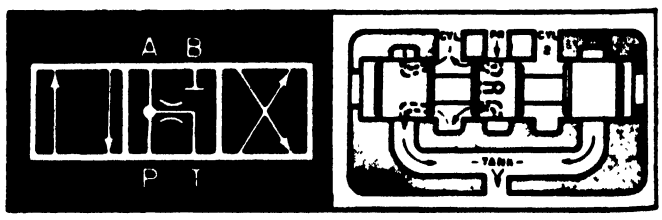
4-Way, 3-position, tandem center



4-Way, 3-position, pump port blocked in neutral cylinder ports connected to tank

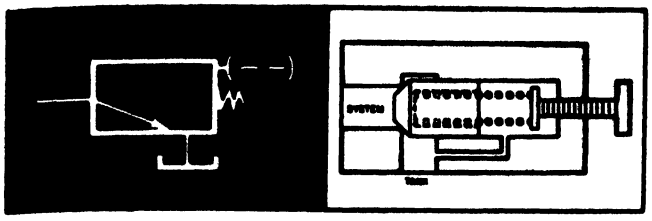


4-Way, 3-position, tank port blocked in neutral cylinder ports connected to pump

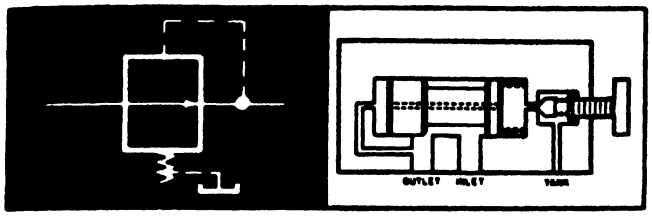


4-Way, 3-position, one cylinder port blocked in neutral, other cylinder port and pump port connected to tank through restriction

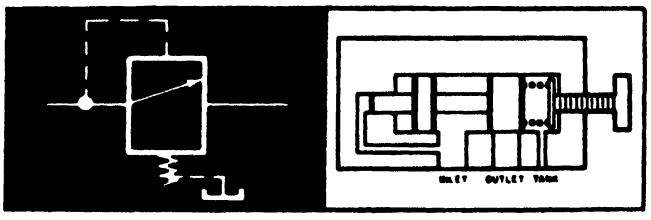
Pressure Controls



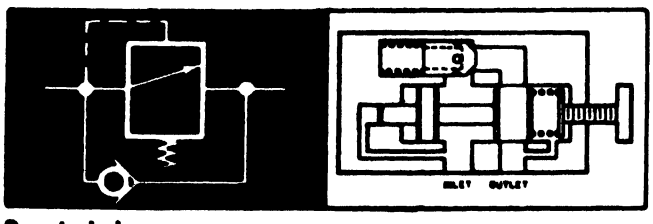
Relief



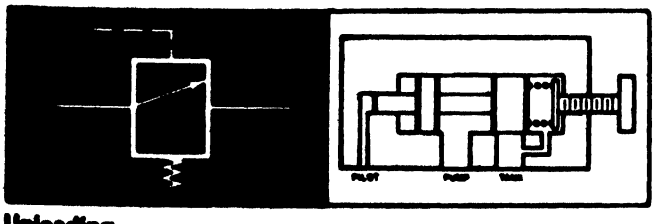
Pressure reducing



Sequence



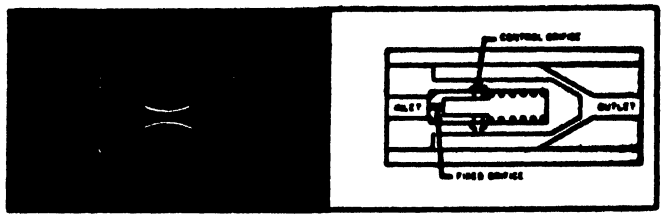
Counterbalance



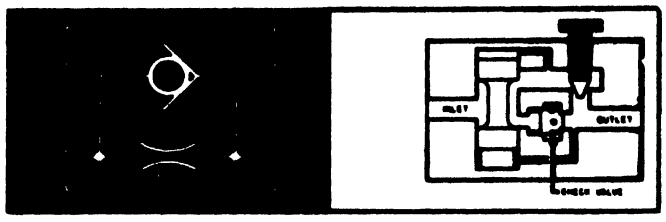
Unloading

Flow Controls

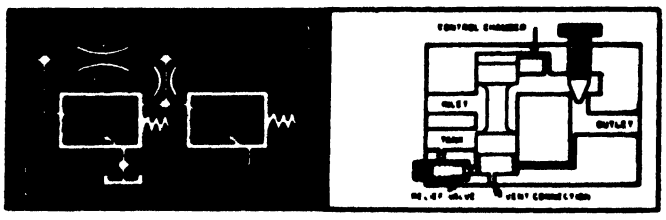
Needle or restrictor



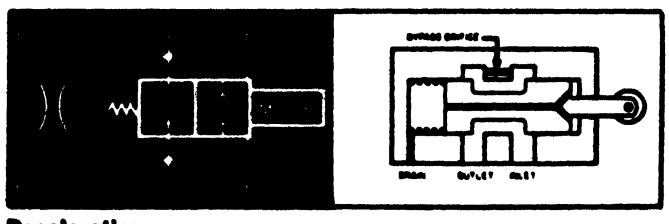
Fixed flow, pressure-compensated



Pressure-compensated, variable, with free reverse flow check valve



Pressure-compensated, variable, with overload relief valve



Deceleration

Advances in Centralised Control and Automation

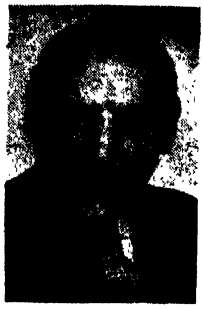
Abstract
The rationalisation and integration of equipment in the wheelhouse of fishing vessels was discussed at the Second World Fishing Boat Congress held in Rome in 1959. At that time it was suggested that the use of centralised control in the bridge structure could add to the efficiency of fishing operations. This paper discusses and gives examples of how the integration of steering and engine controls in the wheelhouse has progressed during the past four years. Future trends are discussed.

Progres realises dans l'automation et controle centralise

Résumé
La rationalisation et l'intégration de l'équipement dans la timonerie des bateaux de pêche ont été discutées au Second Congrès Mondial des Bateaux de Pêche, tenu à Rome en 1959. Il fut alors suggéré que l'utilisation du contrôle centralisé dans la timonerie pourrait augmenter l'efficacité des opérations de pêche. La communication explique et cite des exemple sur la facon dont a progressé, pendant les quatre dernières années, l'intégration des contrôles du gouvernail et de la machine dans la timonerie. Les perspectives futures sont aussi discutées dans cette communication.

Adelantos en la centralizacion de mandos y automatizacion

Extracto
La racionalización e integración del material auxiliar en los puentes de mando de los barcos de pesca se examinó en el Segundo Congreso Mundial de Embarcaciones Pesqueras, celebrado en Roma en 1959. Se sugirió entonces que el empleo de mandos centralizados en la estructura del puente podría incrementar la eficacia de las faenas de pesca. Esta ponencia examina y da ejemplos de cómo fa integración de los mandos de govierno y del motor en el puente ha avanzado en los cuatro anos pasados. Se discuten las tendencias futuras.



by
H. E. H. Pain

S. G. Brown Ltd.

IN 1959 a paper was presented to the Second World Fishing Boats Congress in Rome entitled "Centralised Control in Trawlers". At that time, although a great deal had been talked and written about the subject, no general effort had been made to rationalise and integrate the large number of navigational and operational services required in the wheelhouse, particularly of modern deep-water fishing and control vessels. This was due not so much to lack of knowledge as to the fact that owners and operators had really not been able to make a definite selection from the multitude of instruments and "gadgets" that were becoming available to assist in fish-finding. It may have been that, because of the wide variety and number of types of equipment, owners and operators had found it difficult to select which were desirable and which necessary for their purpose. Far from the market being oversold, rather it can be said that the market had not yet determined what it wanted.

Another aspect of the problem, which has had some influence on the various ideas put forward, has been the inclination towards stern-trawling instead of side-trawling. This relates not only to deep-water, ocean-going vessels but also to smaller craft.

If such schemes are practicable, there are obvious advantages in consolidating on "one class" type vessels. In the same way and if a single class can be determined, then it is of advantage to consolidate on the same type of equipment, although not necessarily of the same manufacture, in each vessel of that class.

It is now the purpose to illustrate some of the advances made in navigation and operational control in fishing vessels down to and including middle-water types and to postulate ideas and schemes suitable for the smaller craft. The selection has been made at random and the coverage is by no means comprehensive.

The subject matter is broadly divided into three sections. The first having emphasis, deals with basic problems concerning compasses and steering control, the second concerning remote control of main and auxiliary machinery. Finally, an attempt is made to forecast probable trends and tendencies and to look towards a future which is perhaps not very far distant.

Towards integration

In the last four years a great deal has been done in a number of countries towards rationalising the wheelhouse. This rationalisation had and has the primary objective of reducing fatigue and running costs and of increasing operational efficiency, in a number of instances enabling one man, the skipper, to control all the operations of fishing from the wheelhouse. Examples of how this has been done in some British fishing vessels range from a very simple form of gyro automatic steering installed in addition to the normal telemotor in the *Prince Charles*

Fig. 1. A simple form of gyro controlled automatic helmsman.

(Fig. 1), to the complete replacement of the telemotor, illustrated in the auto-electric steering control system installed in the *Ross Renown* (Fig. 2). The wheelhouse of the *Ross Renown* also shows, as a separate feature, a main engine control console sited at the starboard wing fishing position alongside a remote steering control.

The photograph of the wheelhouse of the deep water trawler *D. B. Finn* (Fig. 3) shows a complete control

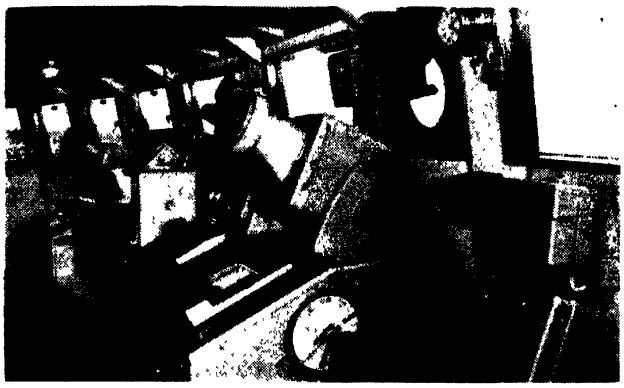


Fig. 3. Complete "one man" centralised control.

console. This includes not only the auto-electric steering control system but also radars, echo sounders, ship shore and close-range R.T. and main engine controls. Provision is additionally made for normal engine room operation of main machinery via engine room order telegraphs.

The illustration of the wheelhouse of the near-water trawler *Hazelhead* (Fig. 4) shows an all-electric steering control system controlling a standard electro-hydraulic steering engine combined in a single console with full main machinery controls. Because of the short-range type of operation of this vessel, automatic steering and gyro compass are not included. Main machinery controls include one-man operation of V.P. propeller, ahead and astern and revolution control.

In all these examples, built-in safety factors are provided by visual and aural automatic alarms.

Fig. 4. Integrated electric steering and full engine control.

Fig. 2. Auto-electric steering control to replace telemotor steering with separate engine control console.

Navigational control

Despite such accurate navigational aids as Decca and, in more extended areas Loran or similar types, the requirement for a north-seeking compass remains and will continue. The modern magnetic compass is a very accurate instrument. While it has the advantage of low cost by comparison with other types of north-seeking compass, it has peculiar limitations in respect of accurate plotting and navigation especially within a defined area. On the other hand, the gyro compass, although more expensive, can provide the essential accuracy required.

Apart from the inherent accuracy of an electrically-driven north-seeking compass and its built-in ability to transmit heading reference to remote positions, the particular advantage, because of its transmitting facility, has been to act as datum for automatic steering. In this connection it must be emphasized that there are no problems in hand or automatic steering control that are essentially peculiar to fishing vessels. The problems of navigation at sea are very much the same, whether the vessel be very large or very small, and are a function of the distance it is required to travel between two points and of travel within an area. In the latter case, trawlers and fishing vessels do have a special problem. To achieve their aim of catching fish, it frequently is necessary to maintain position within certain fairly well defined limits. Echo sounding and plotting devices, the Decca navigator and plotter, together with perhaps plotting types of radar are very useful and the gyro compass proves its advantage over the magnetic.

Here let it be said that one of the disadvantages of the gyro compass has been its size and this has largely been due to sensitivity to ship movement and vibration and the necessity for rather elaborate means of protection against extraneous influences. Modern techniques enable a great reduction in size to be made in the gyro compass.

Automatic steering

There are many advantages in automatic steering, especially those concerned with saving manpower.

The efficiency compared with manual steering increases as weather conditions deteriorate and in any situation it maintains a straighter course with quantitatively less rudder application. This clearly is seen in Figs. 5A and 5B which show the automatically recorded comparison of course and rudder quantity under manual and automatic steering control. Sea conditions moderate, choppy in Force 6 wind. The two records were taken in consecutive periods on the same course.

To try and achieve the best of both worlds, much thought has therefore been given to the problem of providing a transmitting magnetic compass to act as datum for automatic steering in small vessels. This work has been based particularly on the need to reduce the prime and running costs of an automatic helmsman. For a number of years a wide variety of automatic helms-

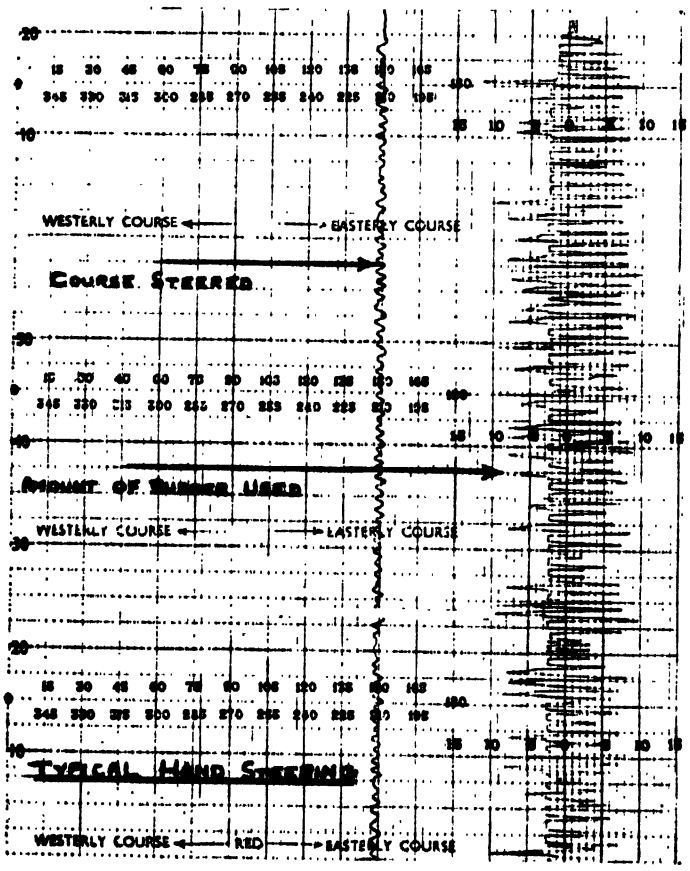


Fig. 5a. Comparison of hand and auto steering.

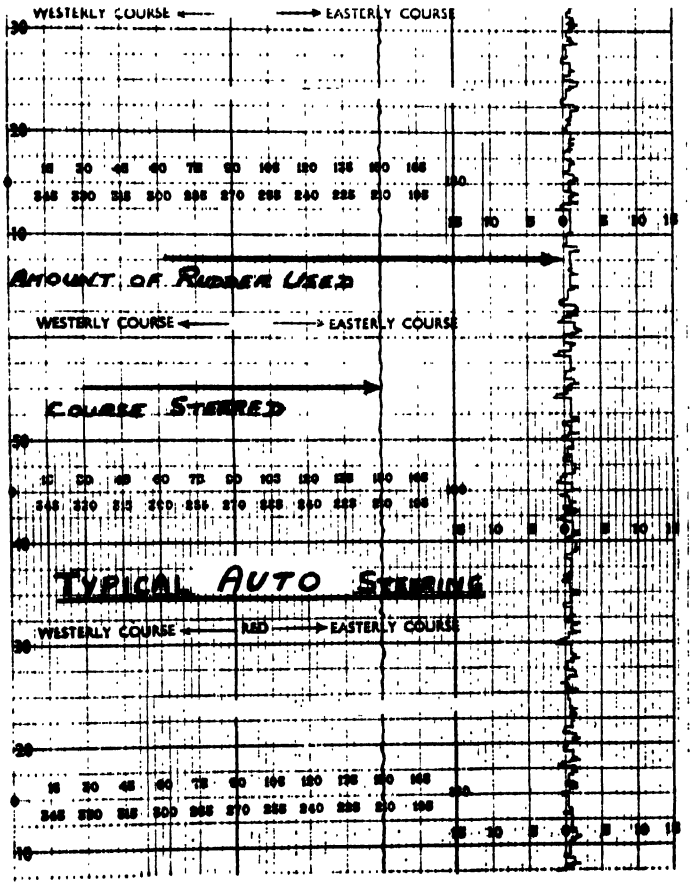


Fig. 5b. Comparison of hand and auto steering.

men using a magnetic datum has been offered but none successfully solve the problem of universal application to all classes of vessel, remembering that the requirement is automatically to steer the ship and not necessarily to provide heading reference to repeaters, radar and other services.

A compromise had therefore to be made between low cost by comparison with gyro controlled automatic helmsmen and efficiency in dealing with the strenuous conditions of fishing.

The problem

It is useful here to review the problem. The magnetic compass should not only be able to act as datum for automatic steering but should be suitable for use as the main and perhaps only compass. It should be suitable for installation as a deckhead compass, for incorporation in a standard binnacle or for installation by itself without a binnacle.

Because the system should have the widest possible application, including very small vessels with perhaps only a one-man crew, it should include some means of indicating that the vessel has gone off the pre-determined course, in fact an "off course" alarm. It should be able to operate from any type of voltage supply AC or DC including 12V, 24V or 32V. It should have the lowest possible power drain, and be suitable for installation in vessels of wood or metal construction. In view of the very small size of many wheelhouses, its operation should not cause magnetic interference.

It should be capable of operating with and controlling any type of power assisted or non-power assisted steering. It should include some means of disconnecting the main steering wheel when the automatic helmsman is in operation and yet provide a rapid means of reverting to hand steering if required.

It is desirable that it should provide some alternative means of hand steering, in or remote from the wheelhouse.

It should be completely weatherproof and have built-in "fail safe" characteristics. As it should require virtually no maintenance at sea, it should be rugged, reliable and capable of operation continuously for long periods in all types of sea and weather.

Its operation should be simple and within the capabilities of the non-technical.

To these major points of the operations problem must be added those of the manufacturer, especially as regards cost. These include that the system should be capable of using a gyro, a magnetic compass or both, in a single installation, as alternative data. The basic system should be capable of controlling any type of vessel from a 30-ft fishing boat to the very largest type of ocean-going vessel. It should be capable of being engineered in a form suitable to meet the space limitations present in many vessels. It should contain as many universally standard components as possible so as to permit easy maintenance anywhere in the world.

There are, of course, other points which will be easily recognised by all those connected with engineering and the operation of vessels, but these are the broad essentials.

A solution

Taking advantage of the advance in automatic control techniques and in the light of the long experience of a number of companies throughout the world, solutions have been found and equipments are now available that incorporate virtually all the features listed.

Within the limitations of this paper it is not possible to describe all the systems but an example has been taken to illustrate the case. In essence it is generally descriptive.

The system is engineered on the "building brick" principle. Thus, the simple requirement for automatic steering can be built up into a sophisticated scheme to cover every requirement. Fig. 6 shows the system in

Fig. 6. Automatic helmsman for small vessels, using magnetic datum.

multi-unit form, including the transmitting magnetic compass. The same system is shown built as a single console, including a gyro compass, in Fig. 7.

It is designed to operate with a fully certificated, transmitting magnetic compass, with any type of gyro compass or with a dual gyro-magnetic installation using either compass as datum. It has a built-in "off course" alarm system to indicate a deviation from the set course by a predetermined amount, thus covering any type of sea and weather condition. It can operate with and control hand or power assisted steering of any type. It can operate in conjunction with telemotor or electric steering control or can replace both to provide a complete steering control system. It can provide complete sophistication, including compensation for yaw and weather and for the load and trim of the vessel, or, in its simplest form, provide just automatic steering. Lever type hand steering or remote steering by push buttons on an extended lead can be included.

It incorporates a special feature that has become extremely useful in controlling a ship when in automatic steering. This enables an alteration of course to be made without reverting to hand steering, a feature particularly valuable in fishing operations. The course can be altered

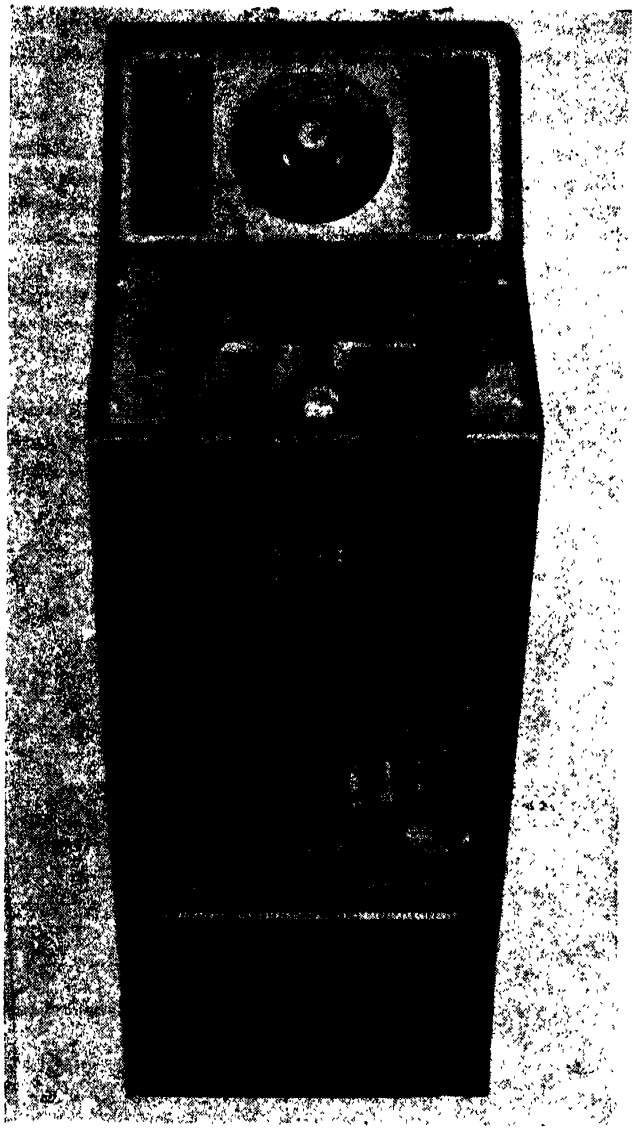


Fig. 7. Integrated electronic steering control console incorporating gyro compass.

round a datum or along a series of tracks with the vessel constantly in automatic control and because of the system's ability to apply "meeting" helm it can come to each new course without overswing.

To illustrate the simplicity of the basic system, Fig. 8 shows in schematic form its application to the very smallest type of fishing vessel with hand steering. Automatic steering is integrated with remote engine control, and it will be appreciated that in the smaller craft this can be extremely valuable in terms of safety and saving in cost and space.

It is very significant that these systems have been developed directly in response to the demands of operators and owners.

Automation of propulsion and auxiliary diesel engines

In the installations shown in Figs. 1 to 4 the main engines are started manually although, in some, remote operation is provided in the wheelhouse. In addition to new electro-mechanical methods of remote manoeuvring controls for single or twin-engine installations as illustrated in Figs. 9A and 9B, it is now possible for systems to give fully automated remote starting for both simple and complex starting procedures as well as full engine control in the wheelhouse. The media for such fully automated systems may be electric, hydraulic, pneumatic or in combination. As with the latest types of automatic steering these new systems are designed on the "building brick" principle, each type of installation giving full protection throughout the starting and stopping procedure.

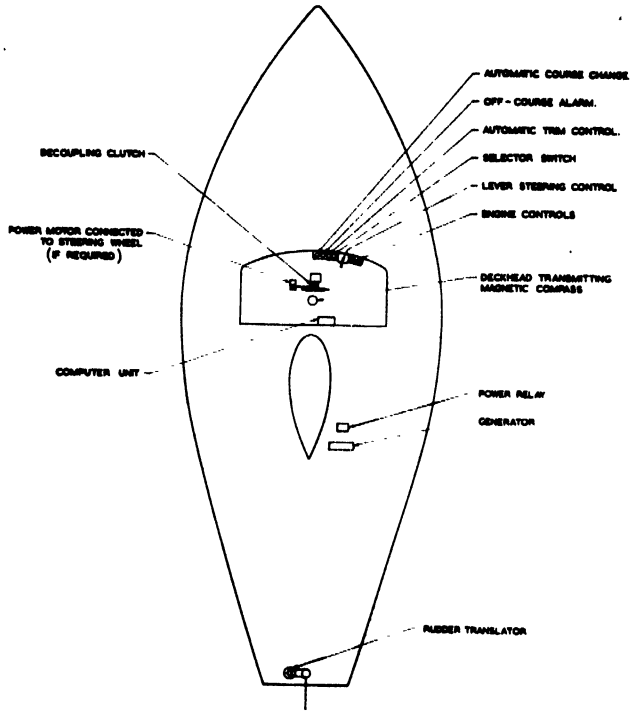
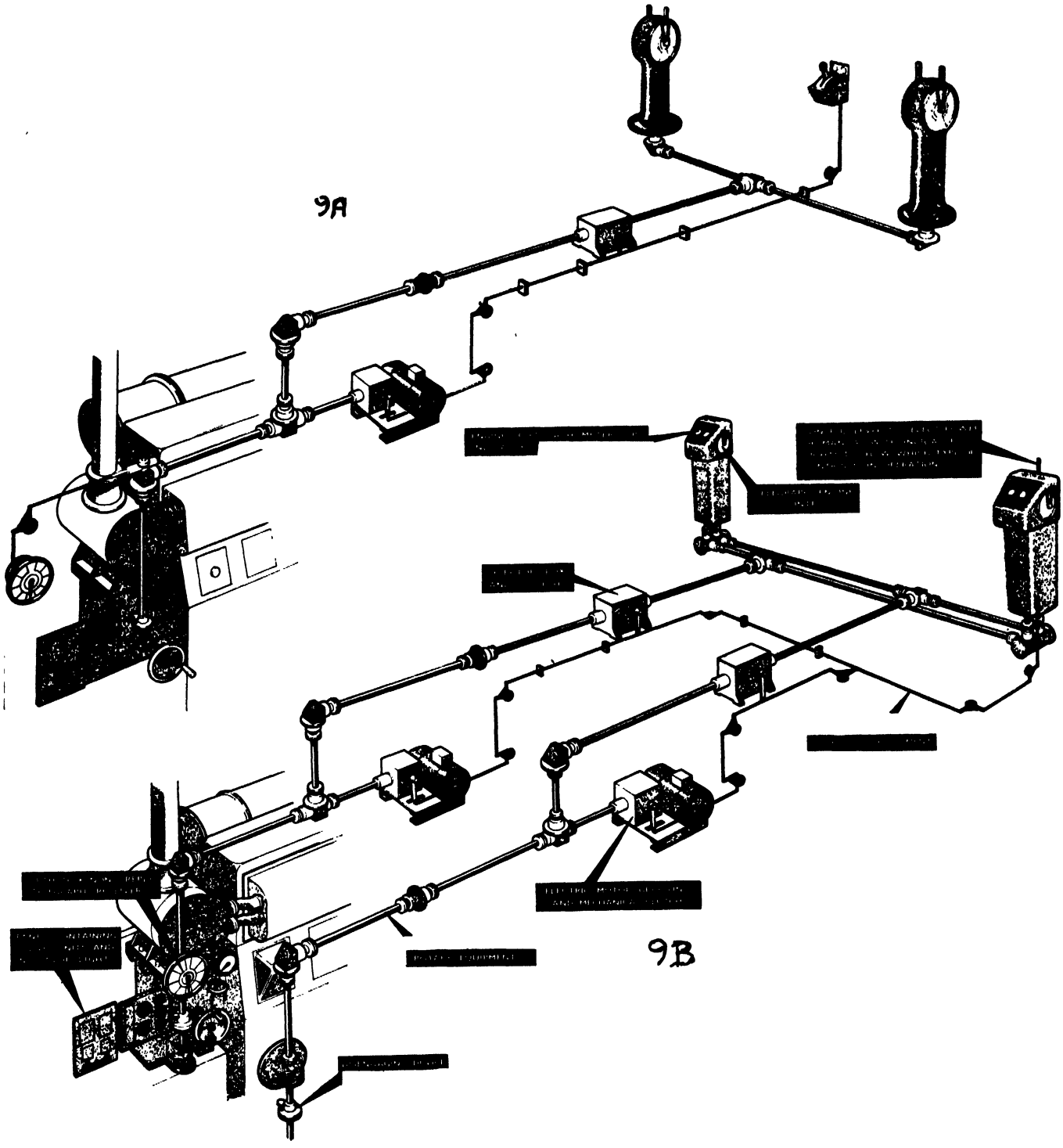


Fig. 8. Schematic layout of integrated automatic helmsman and engine control in small fishing vessels.

Typical operations that can now be automated or remotely controlled in trawlers or, with less complexity, in smaller fishing vessels are illustrated in Fig. 10. It will be seen that these functions can include:

(a) Start and stop of propulsion and auxiliary diesel engines.
(b) Ahead, neutral and astern operation of gearboxes.
(c) Engagement and disengagement of clutches and propeller shaft brakes.
(d) Increase or decrease in engine rpm.
(e) Monitoring temperatures and pressures of engines and associated machinery.
(f) Open and close seacocks.
(g) Control pitch mechanisms on variable pitch propellers.
(h) Malfunction protection and warning equipment.
(i) Main auxiliary service pumps for all duties, for example lubricating oil, fuel oil, cooling water, fire and bilge.



Figs. 9a and b. Electro-mechanical remote manoeuvring control systems for single and twin-engined installations.

(j) Operation of starting air compressors and selection of air bottles.
(k) Fuel and lubricating oil filtering and centrifuging.
(l) Automatic load-sharing and synchronisation of auxiliary electric generators.

In any installation, it can be arranged that no operation commences until the previous processes are working correctly and should any not be completed successfully, provision for more than one attempt can be made. This applies particularly to engine starting and alternator paralleling.

By the selective use of standard equipments, fully automatic multi-engine installations can be operated with fault protection, without human supervision. All controls external to the control system can be interlocked to prevent accidental misuse and visual indicators can be

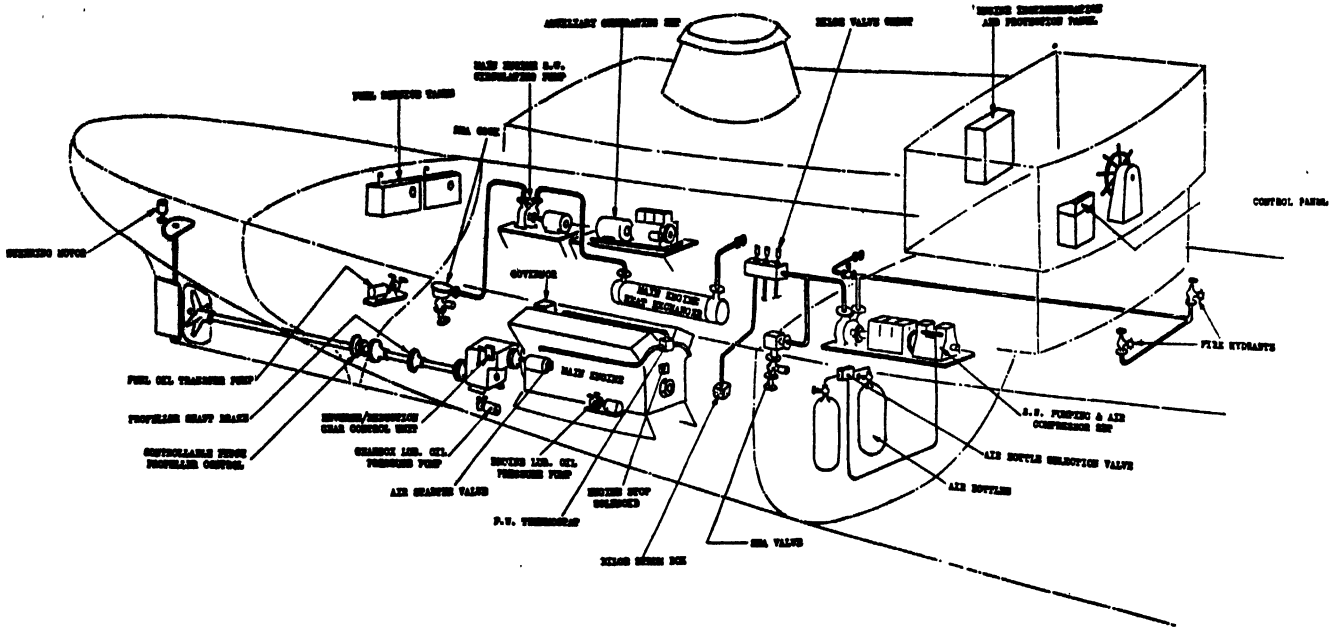


Fig. 10. Typical operations that can be automated or remotely controlled in trawlers and vessels of all sizes. Manoeuvring: (a) Steering motor, (b) Propeller pitch, (c) Reverse/reduction gear control unit, (d) Governor (engine rpm), (e) Propeller shaft brake operation: Starting: (a) Main engine(s), (b) Auxiliary engine(s), (c) Compressor(s), (d) Gearbox lubricating oil pressure pump, (e) engine lubricating oil priming pump, (f) Air bottle selection, (g) Air bottle charging. (h) Air starter valves: Operating: (a) Washing pumps, (b) Bilge pumps, (c) Sea cocks, (d) Fuel oil transfer pumps, (e) Fire-fighting pumps.

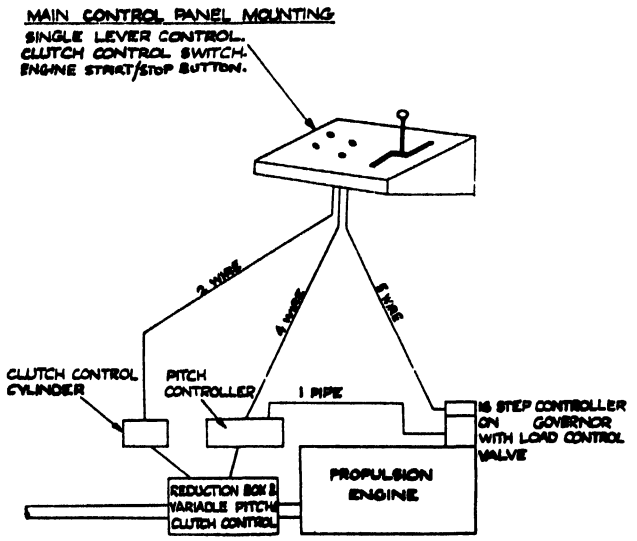


Fig. 11. Examples of remote manoeuvring controls using pneumatic or electro-hydraulic media.

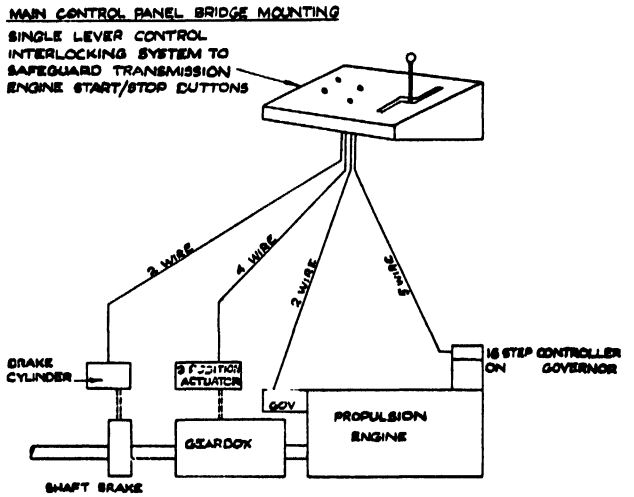


Fig. 12. Examples of remote manoeuvring controls using pneumatic or electro-hydraulic media.

included. All controls can be fitted with manual overrides for emergency use. Provision can be made for the operation of automatic firefighting equipment.

Typical examples of remote manoeuvring controls using pneumatic or electro-hydraulic media are shown in Figs. 11, 12 and 13. A more complex control console designed for installation in a trawler is illustrated in Fig. 14.

The future

With the advent of an electronic automatic helmsman using computer techniques and the practicability of fully automated main and auxiliary machinery control, the way is open to more radical advances. It is perhaps at this stage that we should pause for little while to allow the human operators to assimilate and align themselves with all these new devices.

Attention was drawn by a number of speakers at the Second World Fishing Boat Congress to the fact that the human problem was becoming of paramount concern in many sea-going operations and this applied particularly to such complex operations as fishing.

While the "little" man concerned in comparatively local fishing activity must remain an important factor in achieving an increased haul from the sea, a greater and

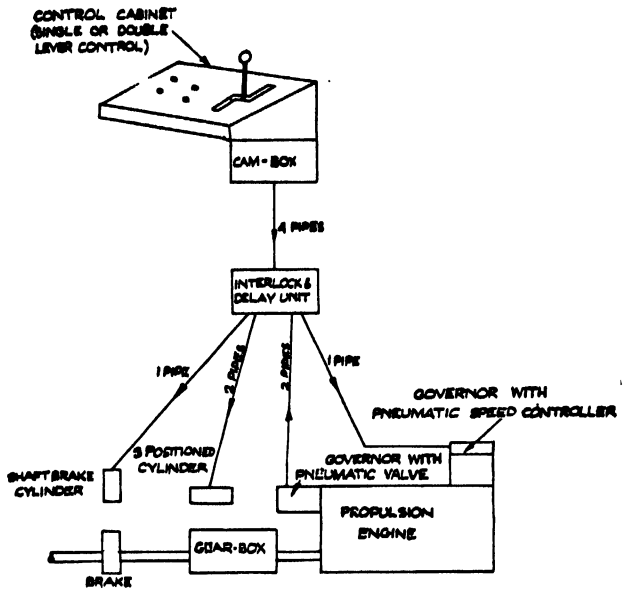


Fig. 13. Examples of remote manoeuvring controls using pneumatic or electro-hydraulic media.

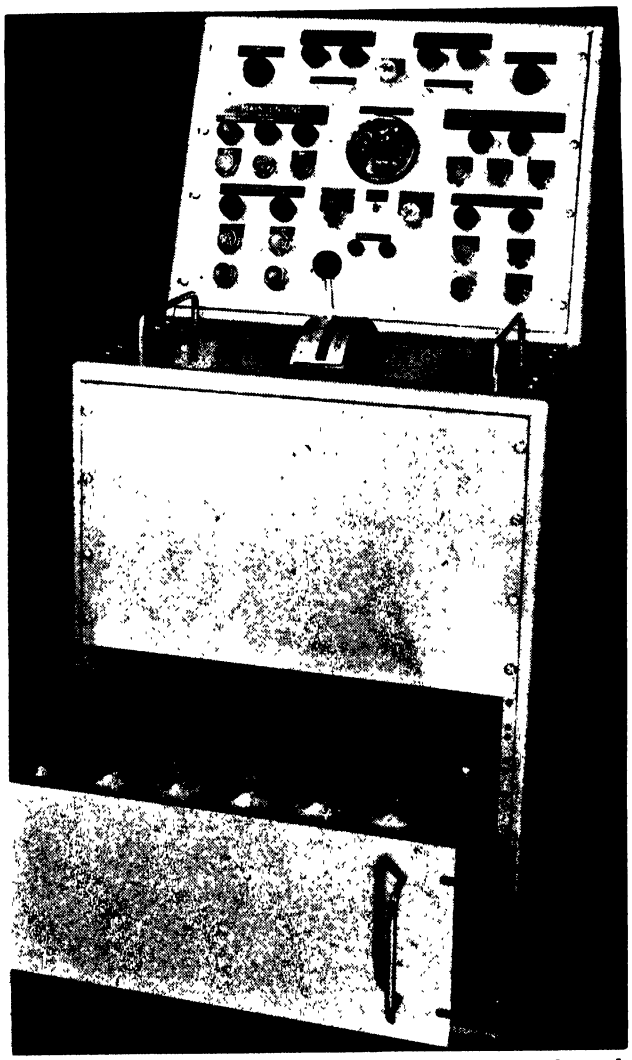


Fig. 14. Trawler type main engine and auxiliary remote-control console.

increasing worldwide demand can only be met by the operation of the bigger type vessels combined perhaps in fleet formation. This inevitably must lead to further requirements for increased automation, designed not only to reduce the human factor and fatigue but also to keep down cost to the consumer.

If fishing vessels and fleets are to operate at long distances from base and for extended periods, some form of precise navigation must be evolved that can be operative equally in clear weather and in the densest overcast.

To operate a fleet in any weather condition an essential feature is accurate position fixing. Advanced forms of navigation using inertial techniques already make this possible, albeit at high cost. Further development will in due course reduce this to a more commercial common denominator. Automatic position-fixing systems using terrestrial satellites are already in experimental form. There is reason to suppose that in the not too distant future it will be possible automatically to resolve a satellite data position fix that will use perhaps Doppler techniques and atomic clocks for time data.

It will be necessary to evolve means in the vessel automatically to evaluate and plot these position fixes and subsequently transfer them in terms of steering control.

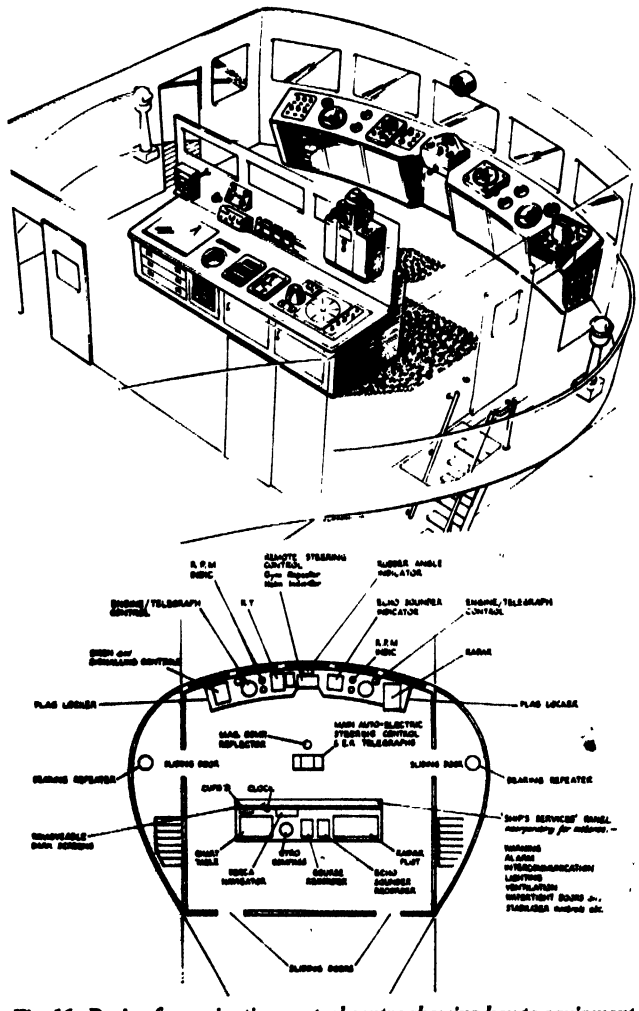


Fig. 16. Design for navigating control centre showing key to equipment.

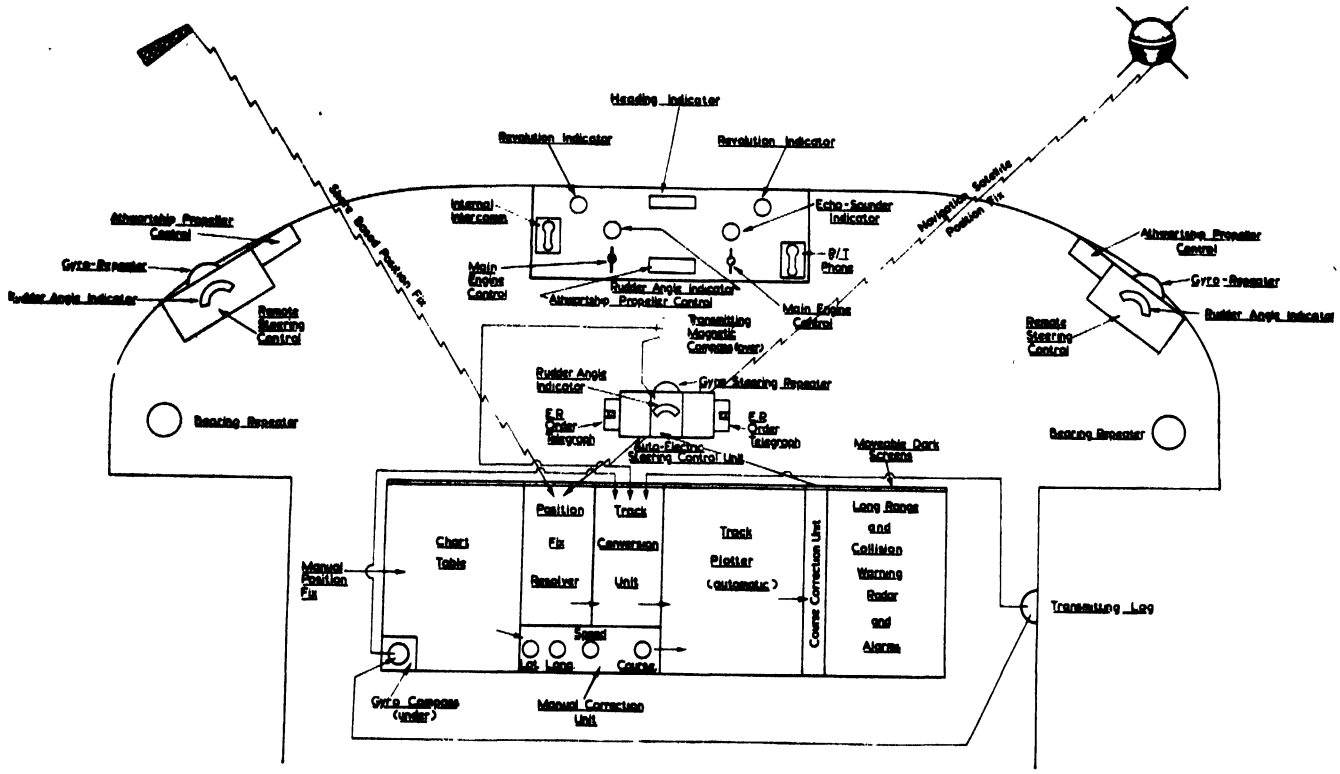


Fig. 15. "Interim" scheme of semi-automatic ship control.

This is possible within the limits of present knowledge and technique although here again the holding factor is cost. Nevertheless, in view of the wide application it will surely be possible for the fishing industry to take advantage of such systems when they are available.

Clearly this is a sphere in which we must "make haste slowly", not discarding old methods until new ones are proved. It would be prudent to introduce a combination system as a first step. Such an "interim" system, using present methods for emergency and close range work and fully automatic means for normal ocean navigation, is postulated schematically in Fig. 15. This diagram deliberately does not attempt to define the actual shape of the wheelhouse itself. This is suggested in the further Fig. 16 which abandons the conventional wheelhouse in

Continued at foot of page 347.

Fig. 17. Example of integrated control console.

Driftnet Hauler for Salmon Fishing

Abstract
In the Japanese North Pacific salmon fishery each driftnetter of about 85 GT carries 260-300 nets, each 50 m long by 7-8 m deep. Thus the combined length of the nets is less than 15 km. In the early years nets were hauled by hand at a rate of about 30 nets (1,500 m) per hour. However, since 1954 mechanical nethaulers have been adopted, with which as many as 70 nets (3,500 m) can be hauled per hour under normal conditions. Only the leadline of the nets is hauled mechanically. Various models have been produced but all the variants can be grouped under three main types:

(a) I-type, where the leadline passes around three pulleys (Figs. 1-3).
(b) S-type, with a centre sheave which consists of two wheels with a V-shaped groove between them (sometimes of variable-gap) in which the leadline is wedged while passing over the upper half of the sheave (Figs. 4-7) (The I- and S-type are mechanically driven).
(c) Hydraulic nethaulers are exemplified by the SU-type with a variable-gap sheave on a semi-rotating head (Figs. 9-10).

Mechanically-driven haulers need 7·5 hp but the hydraulic type 10 hp. The leadline is hauled at a rate of 40-80 m per minute, depending on sea conditions and catch. The I-type hauler needs a railroller but can be converted into a longline hauler. Nethaulers discussed in this paper cost from 250,000 to 300,000 yen (U.S. $700-$830).

by
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Treuils de filets maillants pour la pêche au saumon

Résumé
Dans la pêche japonaise du Pacifique Nord, les bateaux sont de 85 tonnes et utilisent de 260 à 300 filets, chaque filet ayant 50 m de long et 7 à 8 m de chute. La longueur totale de ces filets est donc moins de 15 kilomètres. Autrefois les filets étaient remontés à la main, à une vitesse de 30 filets par heure (1,500 m). Depuis 1954, des treuils mécaniques permettent de remonter, dans des conditions normales, jusqu'à 70 filets par heure. Pendant l'opération la ralingue inférieure seule est enroulée par le treuil.

Il existe différents modèles de treuils mécaniques que l'on peut classer en trois catégories principales:

(a) Type "I" actionné mécaniquement où les lignes à plombs passent entre trois poulies.
(b) Type "S" actionné mécaniquement dont la poulie au centre est composée de deux pièces formant un V et dont l'écartement variable saisit la corde pendant son passage (voir Fig. 4 à 7).
(c) Type "SU" actionné hydrauliquement et dont les poulies composées de deux pièces à écartement variable, sont montées sur une tête semi-rotative (voir Fig. 9 à 10).

Les treuils mécaniques fonctionnent avec 7·5 cv tandis que pour le type hydraulique une puissance de 10 cv est nécessaire. La vitesse de halage varie de 40 à 80 m par minute selon les conditions de mer et l'importance de la capture. L'emploi du type "I" nécessite un rouleau de plat-bord mais il peut être utilisé aussi comme treuil de longue ligne. Les treuils à filets maillants cités dans cette étude coûtent de 250,000 à 300,000 yen (U.S.$: 700 à 800).

Haladores de redes de deriva para la pesca del salmon

Extracto
En el Pacífico septentrional los japoneses pescan salmón con redes de deriva desde embarcaciones de unas 85 toneladas, cada una de las cuales lleva de 260 a 300 secciones de red de 50 metros de longitud por 7 a 8 de altura con las que forman andanas de menos de 15 km. Las redes se solían izar a mano a razón de unas 30 secciones (1,500 m) por hora, pero desde 1954 se emplean haladores mecánicos con los que se recogen hasta 70 secciones (3,500 m) por hora en condiciones normales. Solamente la relinga de plomos se iza mecánicamente. Se han construído varios modelos de haladores todos los cuales pueden agruparse dentro de tres principales (2 mecánicos y 1 hidráulico):

(a) modelo "I", en el que la relinga de plomos pasa por tres poleas (Fig. 1-3).
(b) Modelo "S" con una roldana central formada por dos ruedas con un espacio en V entre ellas (algunas veces el espacio es variable) en el que la relinga baja se acuña al pasar por su mitad superior (Fig. 4-7);
(c) Los haladores hidráulicos están representados por el modelo

Continued from page 346.

favour of a "control centre" which might form the upper compartment in the bridge structure.

These two suggestions are admittedly sophisticated and applicable to the larger type of fishing control vessel, but they are useful to illustrate the philosophy which has application to smaller classes of vessels using far simpler systems.

Fig. 17 illustrates that some forms of these systems have already been introduced. The main console includes auto-electric steering control.

Conclusion

It has to be accepted that automation will take its place in every sphere of fishing and general ship operation. The only matter of controversy is the degree and speed with which it can safely be introduced. Whatever the speed of advance, it must be agreed that no system will be able completely to dispense with the obligation to maintain an adequate visual "lookout" and that no automatic device will replace the human element in taking the final decision and action in emergency.

In the sphere of fishing operations it is pertinent to recall the thoughts shared by the Chairman of the Second World Fishing Boat Congress held in Rome, the late Cecil Hardy:

"An early decision by the owner to take advantage of centralised control would enable the naval architect to prepare the most economical wheelhouse design, leading to a change in the size and shape of the bridge and a saving in weight and cost. Installation problems would be modified and streamlined. An economy in manpower would be achieved with, at the same time, reduction in fatigue and increase in operating efficiency."

"SU" con una roldana de garganta variable en una cabeza semigiratoria (Fig. 9-10).

Los haladores mecánicos tienen motores de 7·5 hp y los hidráulicos de 10 hp La relinga se iza a razón de 40 a 80 metros por minuto según las condiciones del mar y la cuantía de la captura. El halador "I" necesita un rodillo en el cairel, pero éste puede aprovecharse para izar palangres. Los haladores mencionados en esta ponencia cuestan de 250,000 a 300,000 yen (700 a 830 dólares EUA).

AFTER a long suspension during World War II, the international conventions on fishing on the high seas between the Governments of Canada, Japan and the U.S.A., signed in 1953, made it possible for Japanese fishermen to catch salmon in the vicinity of the Aleutian Islands. Since 1956, salmon fishing by Japanese boats off the Kamchatka Peninsula (U.S.S.R.) has been placed under agreements between the countries concerned. Almost all the fishermen who fish for salmon in these areas, as well as in their home waters, have been employing driftnets.

Generally speaking, one net section of a fleet of driftnets used for salmon measures 50 m in length and 7 to 8 m in depth; an average driftnetter of about 85 GT carries 260 to 300 such nets on board. On the fishing grounds a number of nets are connected end to end and set out for a distance less than 15 km. In the early years, the nets were hauled by hand at a rate of about 30 nets (a total of 1,500 m) per hour. This took long hours since the combined length of the nets set by one boat would cover several miles. In 1954 a mechanical hauling device much improved the operation, as it enabled the fishermen to haul as many as 70 nets (3,500 m) per hour under normal conditions.

The first model of nethaulers introduced was an engine-driven three-pulley system, called an I-type. Some of the modifications that followed were the use of a sheave with a deep V-shaped groove; hydraulic drive, etc. Various models have been produced by the same or different

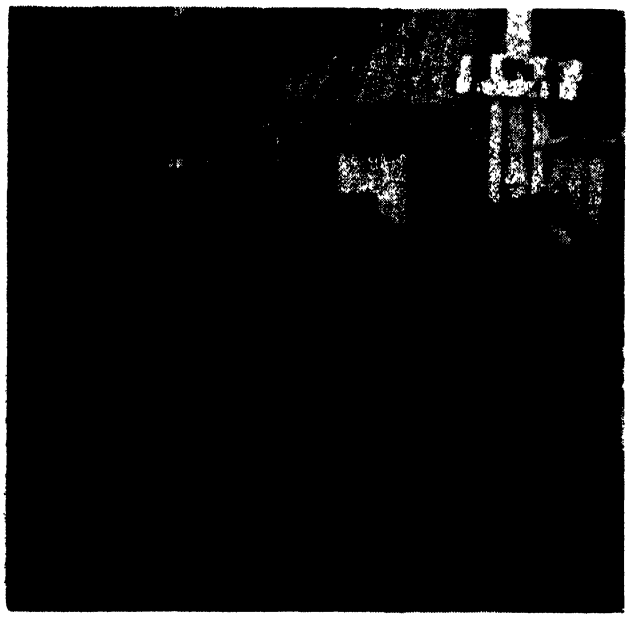

Fig. 1. Operation of I-type nethauler on board.

makers and brought into use in close succession, but these are all variants in their working principle on one or other of three main types. For this reason, it seems best to give a brief description of each one of these types in regard to their construction, performance, relative advantages, and other pertinent information about them.

I-type nethauler

Figs. 1, 2 and 3 illustrate the I-type, model 63-B, nethauler, as viewed from the bridge and the centreline of a fishing boat. The body is made of cast steel. The lower part houses the power transmission and clutch, etc. A speed governor in the middle part responds to any excessive strain on the net from heavy seas or from an unusually large catch. The aft side of the head of the

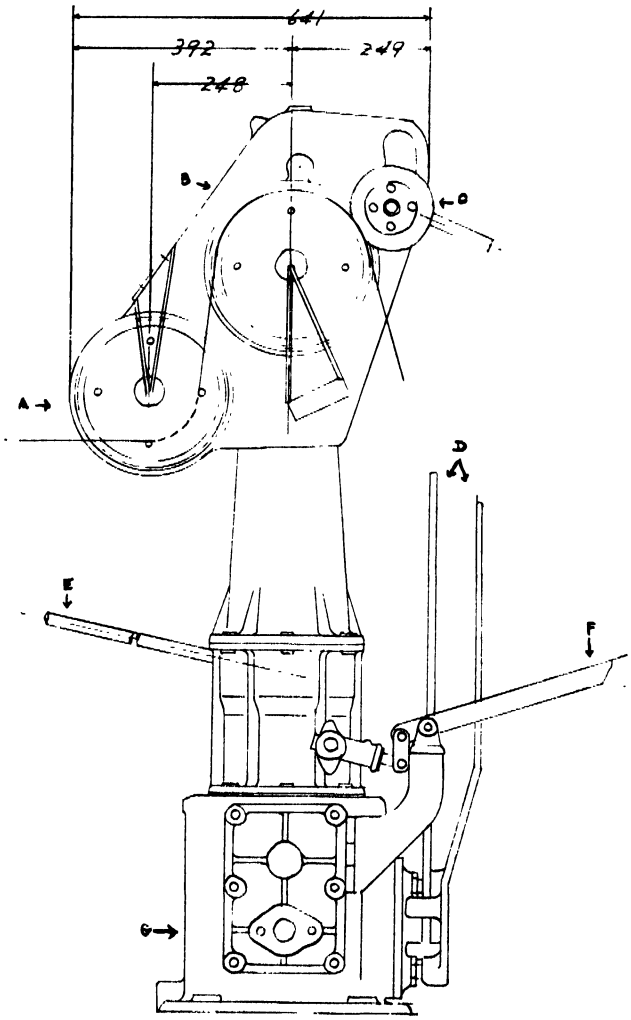

Fig. 2 Construction of I-type nethauler as viewed from bridge. A. Guiding roller. B. Driving pulley. C. Pressing wheel. D. Gear levers. E. Hand clutch. F. Clutch pedal. G. Driving shaft.

hauler has three pulleys with which the leadline of the net is hauled. These consist of a guiding wheel, a driving wheel and a pressing wheel (A, B, and C in Fig. 2), each made of gunmetal and rubber-covered. The grooved wheels are so arranged that the leadline forms a smooth

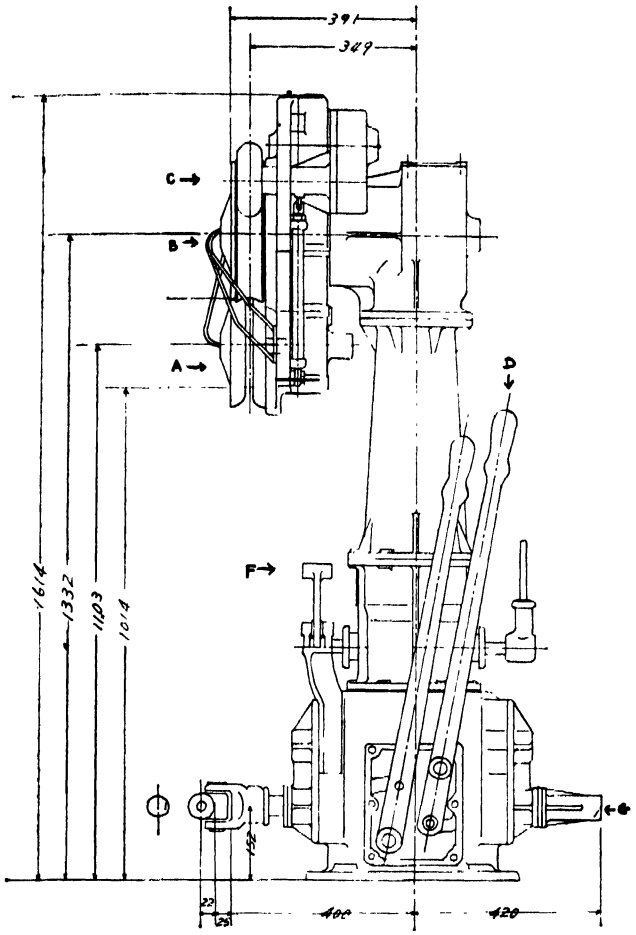

Fig. 3. I-type nethauler viewed from ship's centreline.

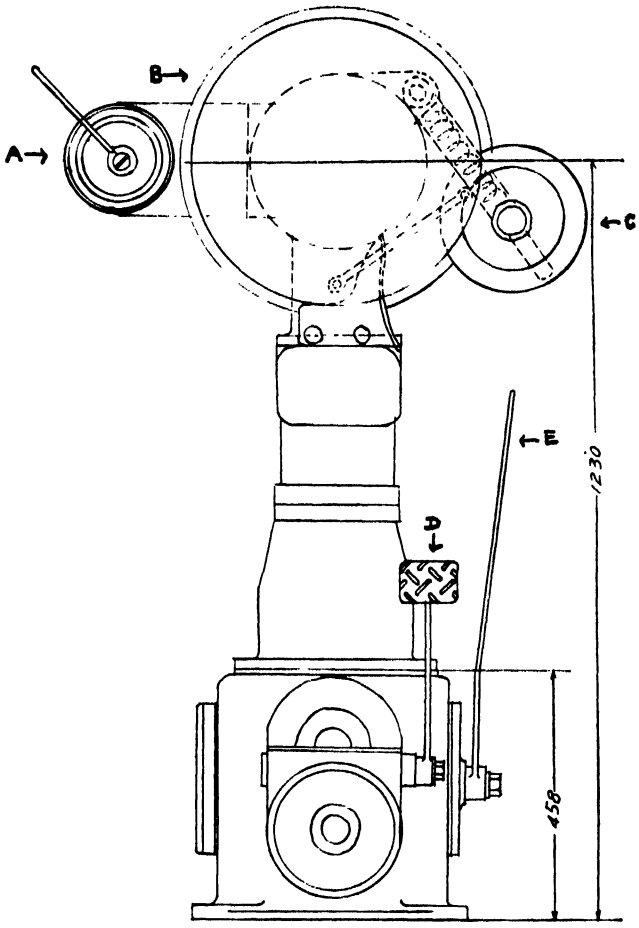

Fig. 4. Construction of S-type nethauler as viewed from bridge. A. Guide roller. B. Driving sheave. C. Press-wheel. D. Clutch pedal. E. Gear lever.

S curve passing over a semi-circle of each of the wheels. Only the leadline is hauled by the grooved wheels while the slack net and floatline is hauled by hand. The outer sides of the wheels are partly covered with shields which keep the net from chafing or tangling on the rotating wheels.

When hauling the net, it first passes over a railroller fitted on the bulwark. Then the leadline is passed under the guiding pulley and over the driving sheave for about half the perimeter. The spring-loaded pressing wheel on the inboard side presses the leadline into the groove of the driving sheave so as to secure a suitable traction. Once fitted into the wheels, the line is automatically hauled without the intervention of a deck hand. By manipulating a clutch the hauling can be stopped at intervals for removing fish from the net.

With the I-type nethauler a railroller is used for guiding the net over the bulwark. This is an upright wheel, mounted on a semi-rotary base, fitted on the railing abeam of the hauler. As the base can turn horizontally within an angle of 90°, the roller leads the leadline properly to the hauler regardless of the direction at which the line comes to the boat.

S-type nethauler

Figs. 4 and 5 show the S-type, model 38, nethauler. The

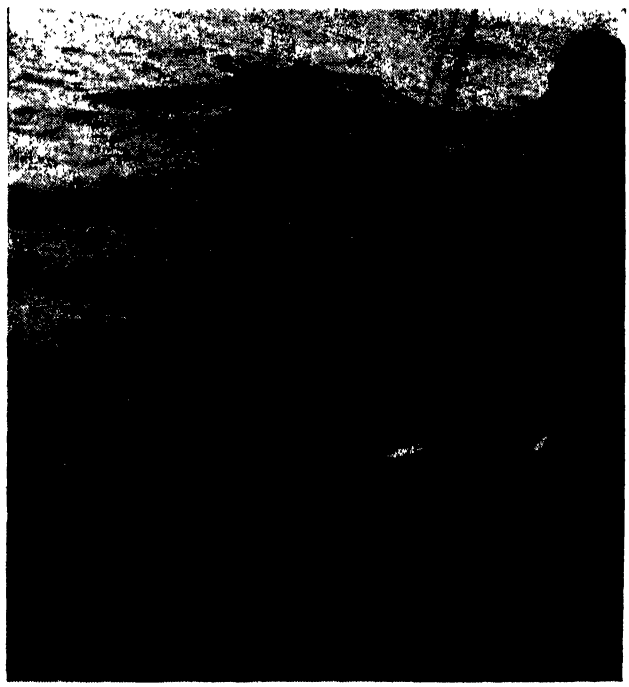

Fig. 6. Single drum nethauler working.

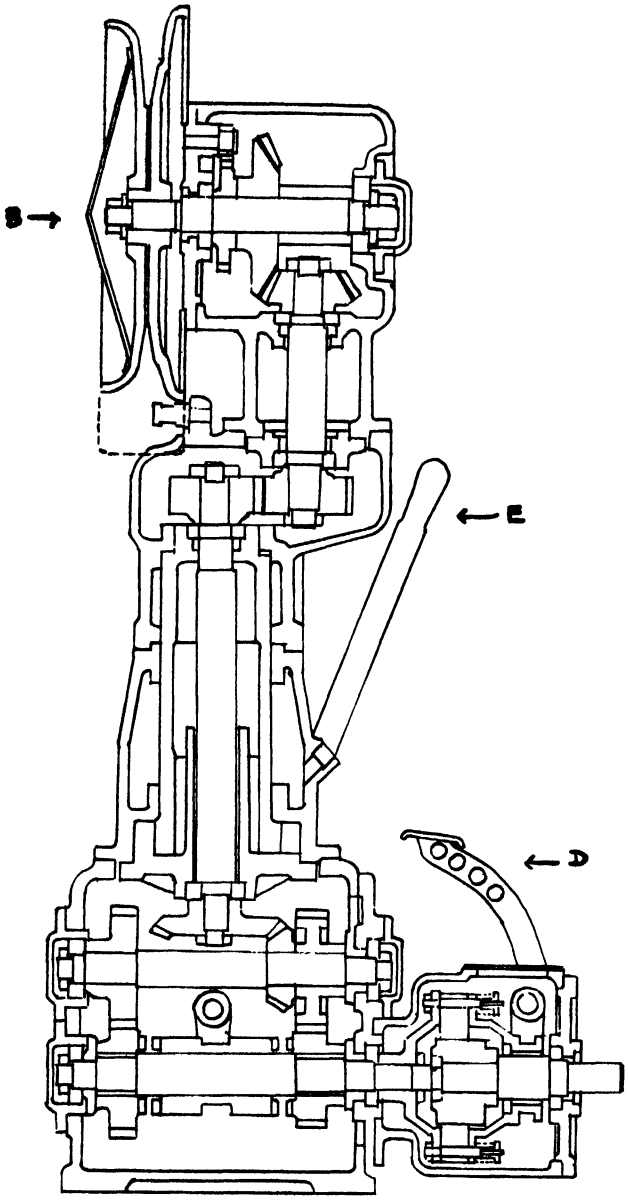

Fig 5. S-type nethauler from centreline.

main difference of this type from the one described above lies in its centre sheave, which consists of two wheels with a deep V-shaped groove between them. Passing over the sheave the leadline is wedged into the groove. The nethauler is mounted on a pivoting base so the sheave can be horizontally turned to any direction within an angle of about 130°.

Fig. 6 shows a single-sheave nethauler of NT-type in operation.

Another model of the sheave nethauler, called YM-type, has a special spring arrangement which always forces the upper half of the outer wheel to incline a little toward the inner wheel, as seen in Fig. 7. Thus, while the upper sector of the sheave grips and pulls the leadline, the lower half of the sheave readily releases the line to coil on the deck.

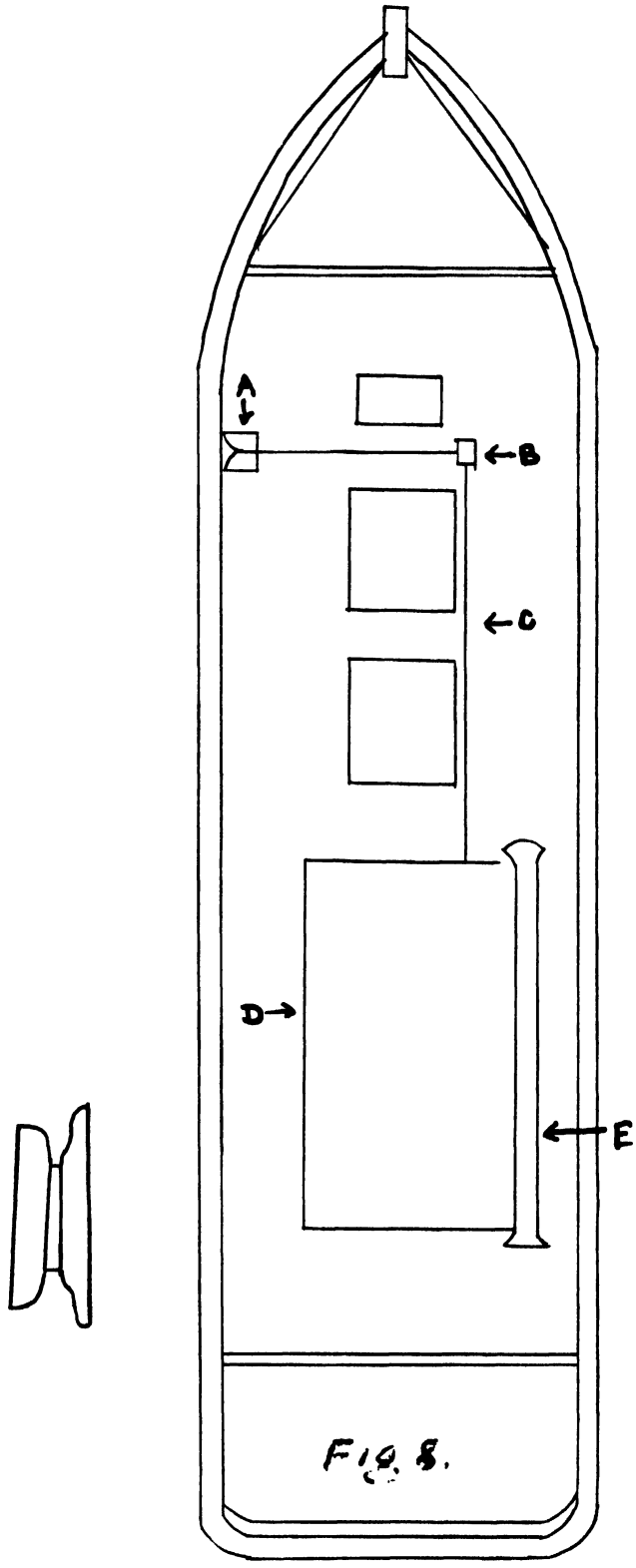

Fig. 7. (left) Drum of YM-type nethauler.

Fig. 8. Deck arrangement for an engine-driven nethauler. A. Nethauler. B. Gear box. C. Counter shaft. D. Engine room. E. Belt conveyor for transporting nets to the stern.

Fig. 8 is a schematic drawing of the deck arrangement for an engine-driven nethauler.

Fig. 9 shows a more recent model of a driftnet hauler which is driven by a hydraulic motor. It is called the

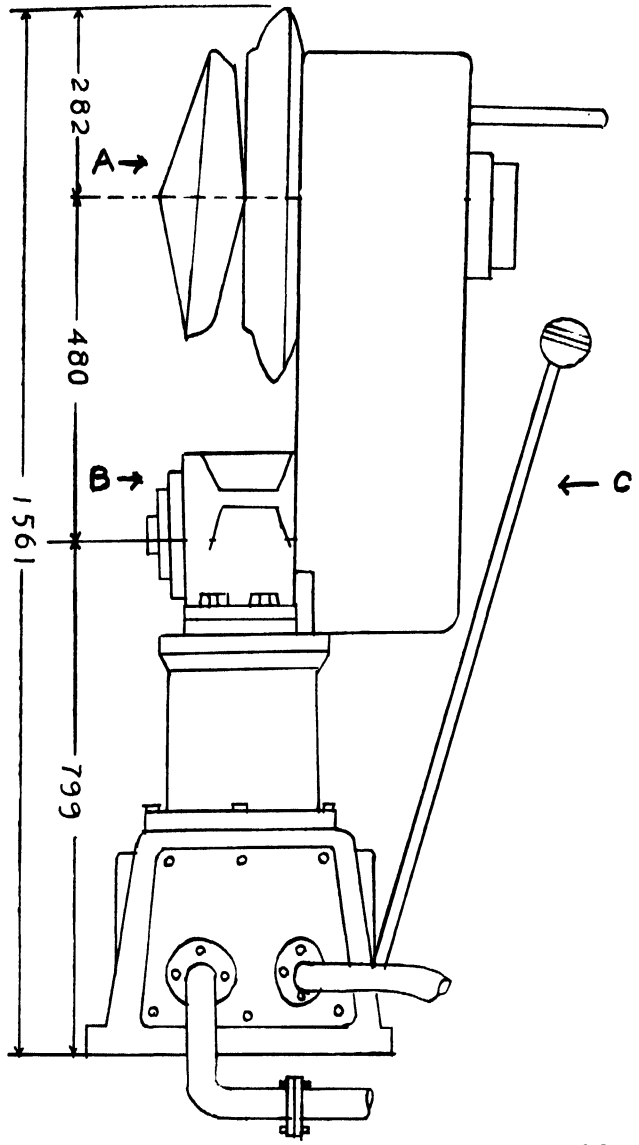

Fig. 9. Construction of SU-type hydraulic nethauler as viewed from ship's centreline. A. Hauling sheave. B. Hydraulic motor. C. Speed regulation lever.

SU-type. The head (containing the hydraulic motor) pivots on the base. The spring-loaded variable-gap arrangement of the upper half of the sheave is similar to that of the YM-type.

The principle of the hydraulic driving arrangement is schematically drawn in Fig. 10. A hydraulic pump is driven by a belt from the auxiliary engine. The pump forces oil to flow through a pipe to the hydraulic motor of the hauler. A control valve regulates the quantity of the oil to the motor, to give a maximum pull of up to one metric ton. The motor is normally built for oil pressure up to 20 kg per sq cm. The nethauling sheave is driven by a chain from the hydraulic motor. The hauler

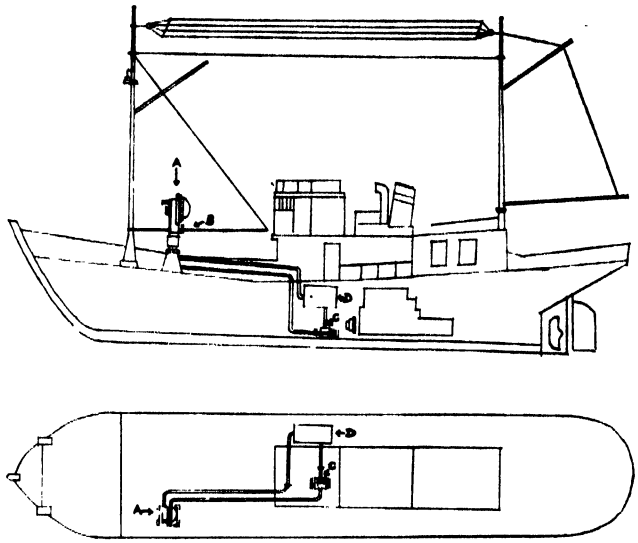

Fig. 10. Deck arrangement for a hydraulic nethauler. A. Nethauler. B. Hydraulic motor. C. Hydraulic pump. D. Oil tank.

can turn from the athwartship line to any required hauling direction within a horizontal angle of 60° towards the bow and 70° towards the stern.

Table I lists the performance characteristics of the various types of driftnet haulers described. An engine output of about 7·5 hp suffices for driving most of them, although a 10 hp engine is needed for the hydraulic nethauler. The leadline is hauled at a rate of 40 to 80 m per minute, depending on the sea and the catch.

Selection of one or the other of these types seems to depend upon the particular duties of the fishing boat concerned, as every type of nethauler has its specific advantage and disadvantage, one setting off the other. For instance, the I-type hauler must be used with a railroller, but it can readily be converted into a longline hauler by interchanging its head section with one for hauling tuna longlines. So far, the other types are not provided with this convenient feature, but they have other advantages, such as the variable-gap sheave and a wide horizontal turning arch to secure a normal hauling of the leadline. The hydraulic nethauler generally performs most smoothly and efficiently. The cost of installation is higher than a mechanically-driven nethauler—about the same as its purchase price. Current domestic prices of driftnet haulers here discussed range from 250,000 to 300,000 yen (i.e., $700 to $830) approximately.

Table 1. Performance characteristics of some Japanese salmon driftnet haulers.(1) (Range of the hauling capacity which depends on loads is not available.)

Type	Height (cm)	Weight (kg)	Revolutions of engine shaft (rpm)	Hauling speed High (m/min)	Hauling speed Low (m/min)	Engine output required (hp)
YM-type	160	600	240 to 280	71–81	57–67	7·5
S-type	160	550	240	71–81	57–67	7·5
YM-type	156	400	120	58–67	50–58	7·5
I-58B	173	395	220 to 300	60–81	40–54	7·5
I-63B	161	395	220	90	60	7·5
SU-type hydraulic	156	300	Not Applicable	75 to 5 to 0		10

Mechanisation of Driftnet Fishing Operations

Abstract
The mechanisation of driftnet fishing operations has lagged behind when compared to other commercial fishing methods. In view of the importance of herring drifting, the Soviet gear technologists and engineers have co-operated in mechanising such operations as far as possible. Hundreds of medium-size vessels have now been equipped with net haulers and net shaking machines, special mechanisms for hauling the bridles and for stowing the warp. The vessels also have machines installed with the necessary conveyor systems for salting the herring. They are, furthermore, fitted out with a warp leader and a net guide which allows the vessel to shoot the nets safely while it is steaming slowly ahead. To avoid snapping of the warp under surge-loads when the vessels operate during poor weather, the warp is led over a shock absorber which can take up a load of up to 3½ tons. The introduction of the mechanisation has increased the rate of hauling and handling the nets during operations and reduced the number of crew required for operating the gear.

Mécanisation des operations de filet à la dérive

Résumé
La mécanisation de la pêche à la dérive ne s'est pas développée aussi rapidement que les autres méthodes de pêche commerciale. Etant donné l'importance de la pêche à la dérive pour les harengs, les technologistes d'engins de pêché et les ingénieurs Soviétiques ont coopéré pour mécaniser ces opérations autant que possible. Des centaines de bateaux de pêche moyens, sont maintenant équipés avec des treuils de filet, des machines à secouer les filets, des mécanismes spéciaux pour haler les brides et ranger les funes. Les bateaux ont aussi des machines pour saler les harengs avec systèmes de bandes convoyeuses. Ils sont équipés avec des conducteurs de funes et un guide de filet permettant de mettre les filets à l'eau en toute sécurité, pendant que le bateau avance au ralenti. Pour éviter que les funes ne se cassent sous l'effet des vagues par mauvais temps, la fune est conduite par un amortisseur de chocs qui peut amortir une force de 3·5 tonnes. L'introduction de cette mécanisation des opérations de pêche a accru la vitesse de halage et réduit l'équipage nécessaire pour l'opération de l'engin.

Mecanización de la pesca con redes de deriva

Extracto
La mecanización de la pesca con redes de deriva ha quedado atrasada con respecto a otros métodos de pesca industrial. Dada la importancia que tiene la pesca del arenque con redes de deriva, los tecnólogos e ingenieros Soviéticos especializados en equipo de pesca han cooperado en la mecanización, en todo lo factible, de tal pesca. Cientos de embarcaciones de dimensiones medianas se han dotado de máquinas haladoras y sacudidoras de redes, y de mecanismos especiales para izar las bridas y adujar el cable; llevan también máquinas con sus transportadores necesarios para salar el arenque y cuentan asimismo con guías para los cables y la red que permiten calar los artes con seguridad mientras se navega lentamente. Para evitar que el cable se rompa por efecto de esfuerzos violentos cuando la mar es gruesa, éste se pasa por un amortiguador con resistencia hasta de 3·5 tons. La mecanización de las maniobras ha incrementado la velocidad de halado y reducido el número de marineros necesarios para manipular el arte.

by
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DRIFTNET fishing operations have lagged behind other commercial fishing methods as regards mechanisation. But Soviet gear technologists and engineers have co-operated in developing different kinds of mechanical deck equipment to reduce some of the time-consuming operations.

Hundreds of medium-sized vessels are now equipped with such equipment which includes net hauling machines, bridle hauling mechanisms, warp stowing machines, net shaking machines, herring salting machines and mechanisation for protecting the warp during very high strain in bad weather; deck gear for shooting the net and instruments for quick measurement of water temperature. The introduction of these new techniques has increased the rate of hauling and handling the nets, has cut labour for catching and processing and has increased the yield of the drifters.

Net chute installation

The best way of setting a herring net of which the warp is underslung, is to shoot from a moving vessel; to prevent fouling by the propeller special gear was developed consisting of a net leader and a warp leader designed to shoot the nets and warp well out from the vessel's side clear of the propeller. The deck arrangement of this for a medium-sized vessel is in Fig. 1. The warp leader consists of a horizontal guide roller, a vertical roller and a retention guide. The vertical roller is mounted on a bracket hinged to the vessel's side which allows the roller to be turned inboard when not in use.

The net leader shown in Fig. 3 is constructed from pipes welded together. It is 6 m in length and 1.5 m in height. The after-ends of the pipes are smoothly bent and connected to the cross-piece so that they lead the net well outboard. A vertical pipe, 800 mm high, prevents the nets leaving the leader. The entire assembly can be easily removed.

Shock absorber

To protect the main warp from overload during bad weather a special shock absorber was developed—Fig. 4. The compression of springs releases a certain length of warp and as soon as the surge-load is removed the springs relax.

The shock absorber consists of a welded housing, energy-absorbing unit and a stress-indicating device. It can withstand a load of up to 3½ tons and pays out six m of warp.

Net hauler

Several machines have been developed for hauling and handling the nets. The hauling machinery shown in Figs. 1 and 5 consists of a driving roller placed on the ship's bulwark, two grooved hauling heads and an

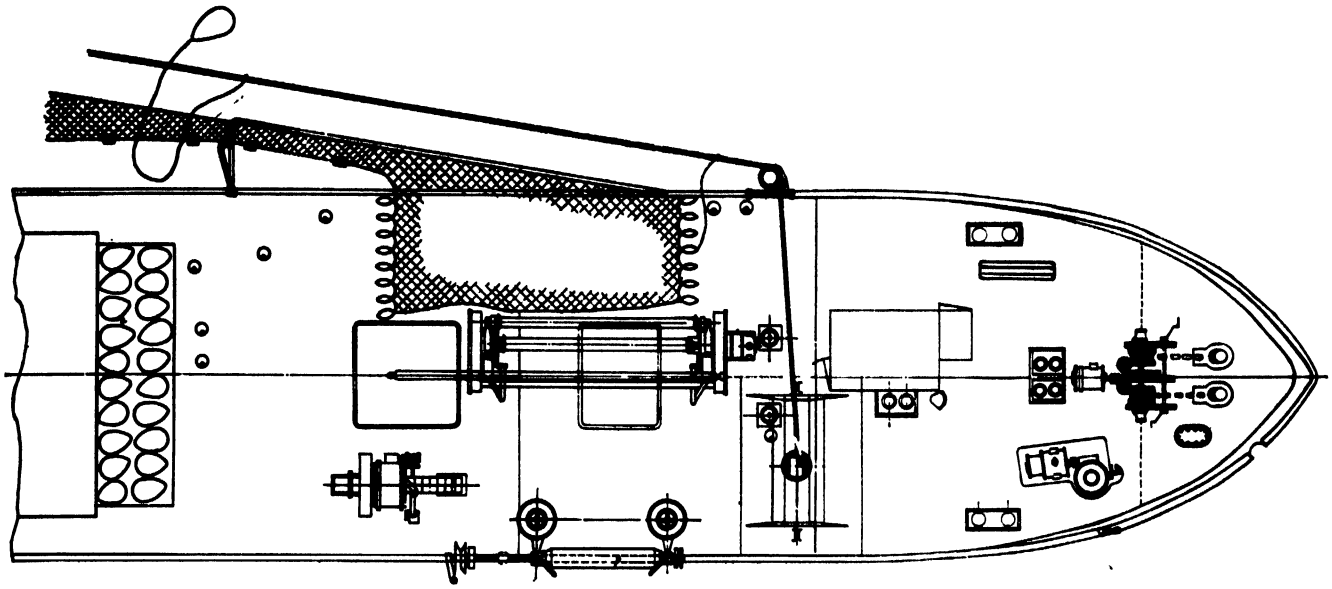

Fig. 1. Deck arrangement of hauling machinery.

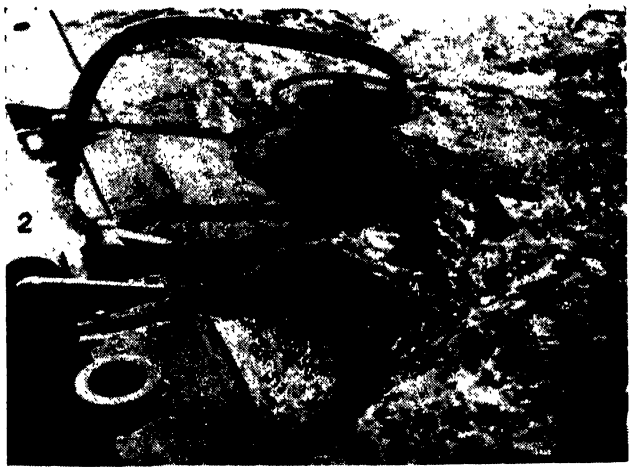

Fig. 2. Warp leader.

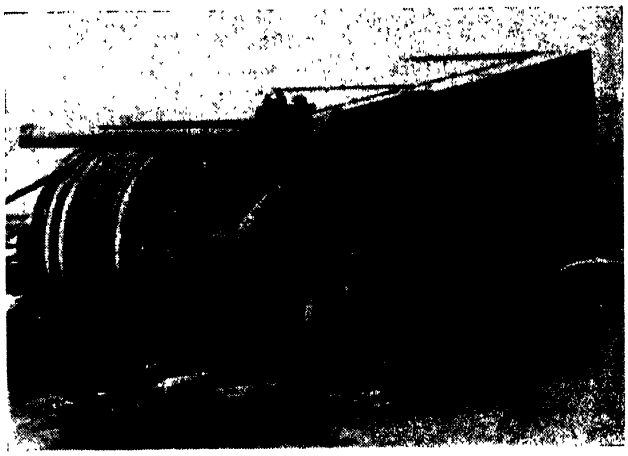

Fig. 4. Shock absorber.

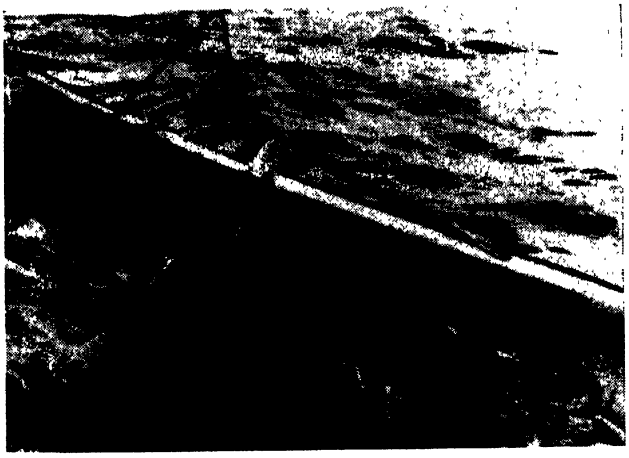

Fig. 3. Net leader.

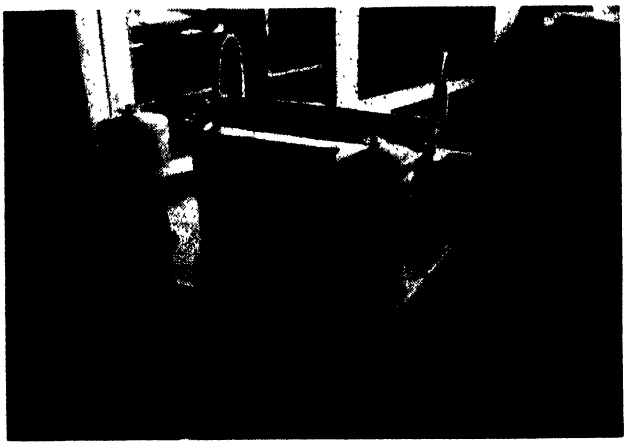

Fig. 5. Model of herring driftnet hauling machinery. The floatlines and sinkerlines are hauled by the vertical gurdies gripping the lines with spring-activated fingers over half the circumference of the head.

apparatus for hauling the bridles which attach the nets to the warp. It is driven electrically by one motor located underdeck. The driving roller can be tilted inboard.

The driftnets are hauled by two hauling heads which grip the lines (floatline and sinkerline) with spring-actuated fingers in the appropriate grooves. With this machinery the hauling rate of the nets is from 15 to 35 m per min. The engine power is 3·7 kw, while the machinery weighs 980 kg.

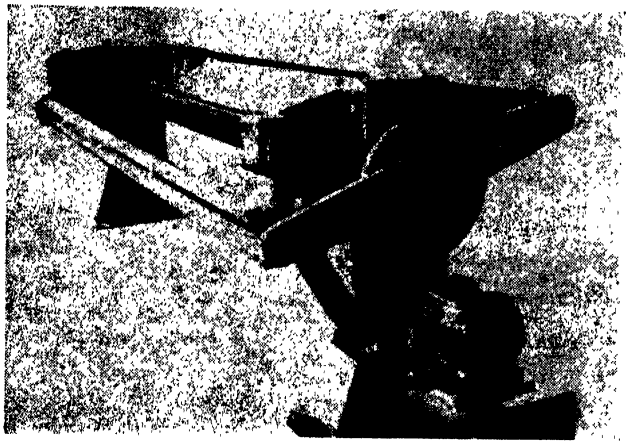

Fig. 6. Machine for shaking fish out of the net.

Driftnet shaker

Shaking the herring from the driftnets is a very time-consuming operation requiring much labour, and machines were introduced which mechanised this operation—see Fig. 6. This machine reduces shaking time to about 1 to 3·5 min per net. It consists of two posts carrying the shakers and two driving rollers for hauling the nets up and taking them to the place of storage. It is installed about amidships (Fig. 1) and is driven by an electric motor of three kw, placed in one of the supporting posts. The shaker vibrates from 165 to 168 shakes per min and weighs 750 kg.

Salting machine

The machine for salting herring (Fig. 7), comprises a conveyor for transporting the fish from the deck, a salt-hopper, a screw conveyor which feeds suitable quantities of salt, and a barrel for mixing the salt with the fish. This mechanisation has considerably raised productivity. The capacity of the salting machine is from $3\frac{1}{2}$ to 4 tons per hour. The machine is driven by a 3·8 kw electric motor and weighs 960 kg.

Warp stowing machine

A special machine has been developed for stowing the net warp in the hold of the vessel (Fig. 8). Installed in

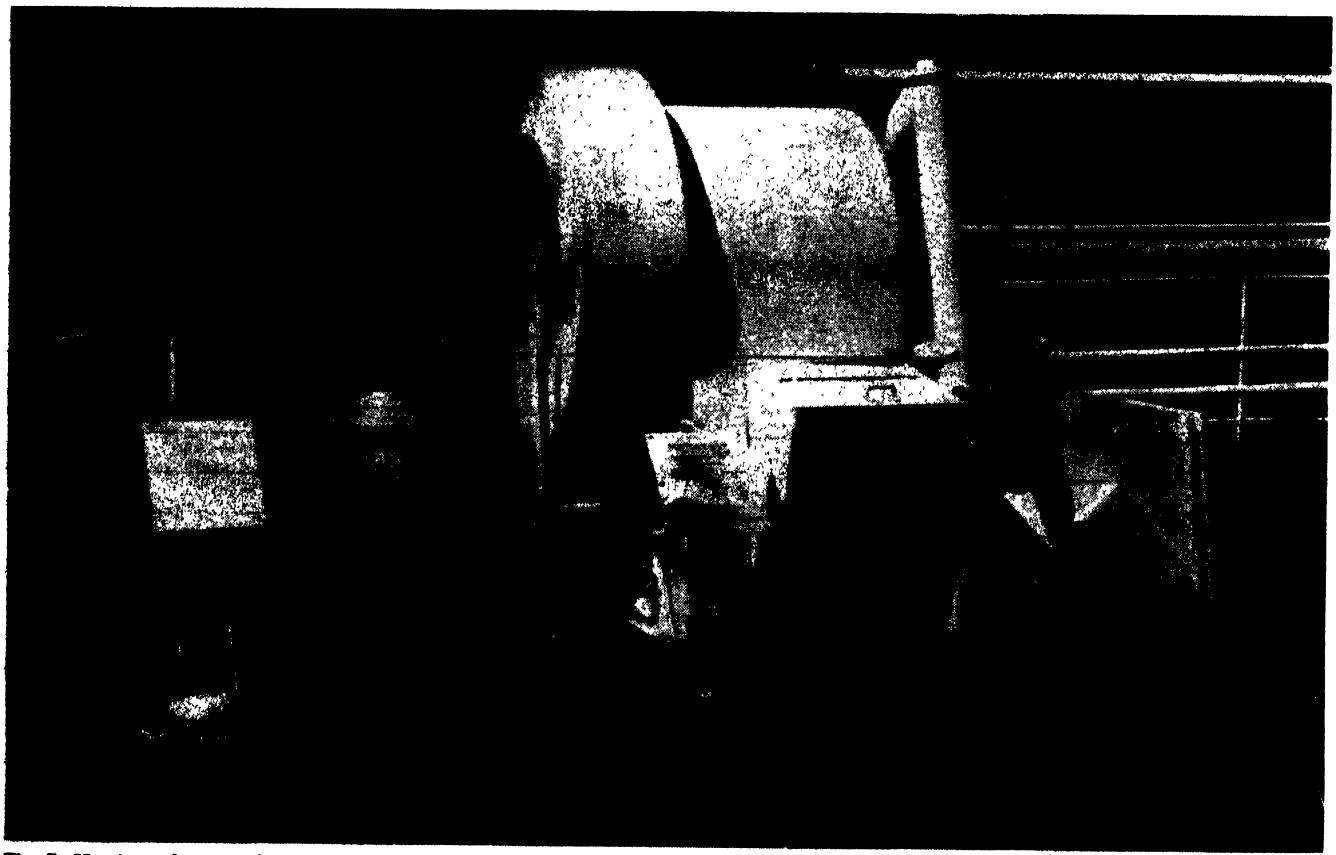

Fig. 7. Herring-salting machinery. At the right-hand side is the slanting bucket elevator for conveying herring from the deck to the central drum where herring and salt are mixed together. The steep tubular screw conveyor feeds salt in metered quantities to the mixing drum. The herring is conveyed from the mixer into the barrel on the left, which stands on a vibrating platform for compacting the herrings into the barrel, thus obviating the need for laying them down by hand, head to tail. H. Kristjonsson photo.

The Complex Mechanisation of Beach Seining

Abstract
Although in recent years commercial fisheries on the high seas have developed extensively in the U.S.S.R., the use of beach seines on shallow coasts and in inland waters is still of importance. Before the Revolution seines provided about half of the total catch and, in spite of the large development in other types of fishing, beach seining still ranks high in the general fish production. The method has now been largely mechanised by fisheries research workers and engineers and, while it was once one of the most laborious fishing methods, the use of new hauling appliances has made possible large savings of manpower. Depending on fishing conditions, the beach seines used in the U.S.S.R. vary from 150 to 2,000 m in length with a height of up to 40 m while the hauling lines may be up to 6,000 m long. The type of hauling appliances used depend on whether the fishing grounds are operated continuously, temporarily or at irregular intervals. In inland waters the seines are operated from self-setting boats on which the nets and lines are flaked down and from which the gear runs out on its own during shooting. Such boats are normally towed by 8-12 m motor boats powered by 6-15 hp engines which develop a speed of up to seven knots. The seines are hauled by winches installed ashore which have a traction force of 1-3 tons and a hauling speed of 6 to 80 m per min. Such winches can be permanently installed or mounted on tractors. Net stowing machines have also been developed so that the net is now reloaded onto the boat mechanically. For marine operations a new type of craft has been developed which combines the function of tug and setting boat. These vessels are 13·5 m long, have a displacement of 10 tons for a draught of 0·75 m and are powered by a 15-hp engine which gives a speed of up to five knots. They are provided with a winch with a hauling power of one ton and a hauling speed of up to 40 m per min. When fully mechanised, these vessels may also carry a seine-stowing machine.

La mecanisation complexe des sennes de rivage

Résumé
Bien que la pêche commerciale hauturière se soit développée ces dernières années de façon considérable en U.R.S.S., l'utilisation des sennes de rivage sur les côtes peu profondes et dans les eaux continentales a encore une certaine importance. Avant la Révolution, ces sennes produisaient environ la moitié de la capture totale et, malgré de grands développements dans les autres méthodes de pêche, la senne de rivage a encore un rang important dans la production générale de poisson. Cette méthode qui demandait beaucoup de main-d'oeuvre dans le passé a été largement mécanisée par les technologistes et les ingénieurs et le halage mécanique a permis de réaliser une économie de main-d'oeuvre. Selon les conditions d'opérations, les sennes utilisées en U.R.S.S. ont de 50 à 2000 m de long et jusqu'à 40 m de haut tandis que les funes mesurent jusqu'à 6000 m. Suivant les lieux de pêche, les dispositifs de halage peuvent être installés définitivement, temporairement ou à intervalles irréguliers. Pour la pêche dans les eaux continentales, les sennes et les funes sont rangées sur un bateau qui les met à l'eau automatiquement; ces bateaux sont toués par d'autres bateaux motorisés de 8 à 12 m, ayant des machines d'une puissance de 6 à 15 c.v. qui développent une vitesse de sept noeuds. Les sennes sont halées par des treuils installés à terre d'une force de traction de 1 à 3 tonnes et d'une vitesse de halage de 6 à 80 m/min. Ces treuils peuvent être fixés au sol ou montés sur des tracteurs. Des machines pour ranger les filets ont été aussi développées de sorte que maintenant les filets sont remis sur le bateau mécaniquement. Pour les opérations maritimes, un nouveau type de bateau qui combine les deux fonctions (remorquage et mise à l'eau automatique du filet) a été développé. Il a une longueur de 13·5 m, un déplacement d'eau de 10 tonnes, un tirant d'eau de 0·75 m et des machines de 15 c.v. lui assurant une vitesse de cinq noeuds. Ce bateau est équipé d'un treuil ayant une puissance de halage d'une tonne et une vitesse de halage de 40 m/min. Lorsqu'il est entièrement mécanisé, ce bateau peut aussi porter une machine à ranger les filets.

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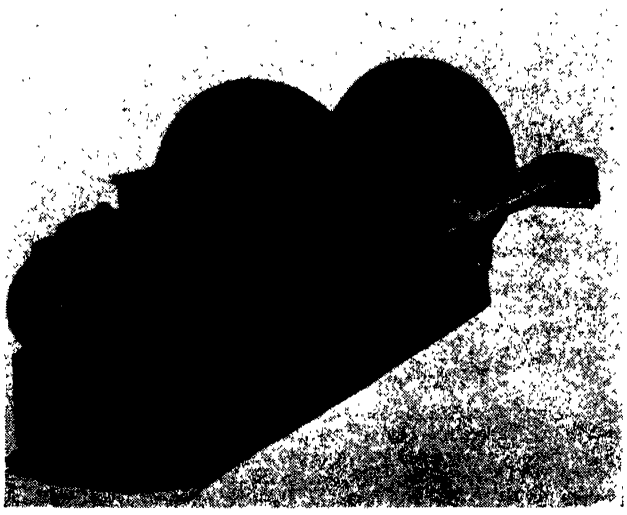

Fig. 8. Machine for stowing the net warp in the hold of the vessel.

the warp compartment of the forehold, it is operated from the deck through stiff rods and pedal gear. It stows the warp at a rate of up to 35 m per minute. When using a 22 mm warp the capacity of its drum is up to 4,000 m. This machine is driven by a 2·8 kw electric motor and it weighs, complete with drive arrangement, 800 kg.

Thermometer

A semi-conductor resistance thermometer which allows remote readings of the sea temperature ensures a constant control of the temperature within the ranges of —2°C to +12°C. The accuracy of the instrument is 0·1°C and it is designed to work from the vessel's direct current electrical system.

Results

Mechanisation increases the rate of hauling and the speed of handling driftnets with a smaller crew. During the last fishing trip of SRT/4256, which is fully equipped with the machines and mechanisms described above, its catch of 62 tons of herring was fully processed and turned over to the mother ship within 24 hours.

La compleja mecanizacion de los artes de playa

Extracto

Aunque en los últimos años la pesca de altura se ha desarrollado extraordinariamente en la Unión Soviética, el empleo de artes de playa en costas someras y aguas continentales todavía tiene importancia. Antes de la Revolución las redes de cerco suministraban cerca de la mitad de la captura total y, a pesar de los muchos adelantos de otras clases de pesca, la que se practica en las playas sigue desempeñando un importante papel en la producción pesquera total. Esta pesca se ha mecanizado mucho por los investigadores pesqueros y los ingenieros y mientras una vez fue uno de los procedimientos más laboriosos, el empleo de la mecánica facilita las maniobras y ahorra mano de obra. Según las condiciones locales, los artes de playa empleados en la U.R.S.S. varían en longitud de 150 hasta 2,000 m y pueden tener una altura hasta de 40 m, en tanto que los cables necesarios llegan a ser hasta de 6,000 m. La clase de dispositivos de halar depende de que los bancos de pesca se exploten continua, temporal o irregularmente. En las aguas continentales la maniobra de los artes se hace desde embarcaciones que calan, recogen y arrollan redes y líneas automáticamente. Normalmente estas embarcaciones las remolcan botes de 8 a 12 m con motores de 6 a 15 hp y con velocidad hasta de seite nudos. Cuando se pesca desde la playa las redes las halan maquinillas instaladas permanentemente en ella o montadas en tractores. Actualmente también se fabrican máquinas estibadoras que meten a bordo la red mecánicamente. Para la pesca marítima se ha proyectado una nueva clase de embarcación en la que se combinan las funciones de remolcador y bote de calamento; tiene 13·5 m de eslora, desplaza 10 tons, cala 0·75 m y lleva motor de 15 hp que le da una velocidad de cinco nudos. Está dotada de una maquinilla con una fuerza de tracción de una ton y una velocidad de 40 m/min. Cuando se mecanizan totalmente estas embarcaciones también pueden llevar una máquina para estibar la red de cerco.

BEACH seining on shallow coasts, in lakes, rivers and artificial reservoirs is still of importance. It is especially popular in the Caspian Sea and in the delta of the Volga River, in the richest inland fishing areas of the Soviet Union.

Beach seining in the past was laborious but with the development of the fisheries industry research officers and engineers developed mechanisation.

The beach seine (Fig. 1) belongs to the filtering type

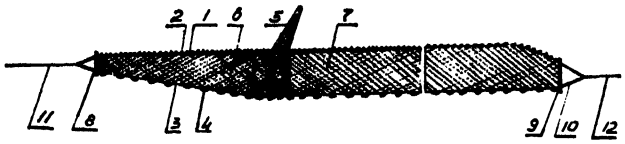

Fig. 1. Beach seines of the river type. (1) Headline (2) Floats. (3) Groundrope. (4) Sinkers. (5) Bag. (6) Shore wing. (7) Tow wing. (8-9) Spreaders. (10) Bridles. (11) Shore line (hook line).

of fishing gears. It consists of a long sheet of webbing hung on the headline and footrope with a centre bag. Two kinds of beach seines can be distinguished: symmetrical seines with the bag in the centre and asymmetrical seines with the bag located close to either end. As a rule seines in lakes or reservoirs are symmetrical while the wings of seines in rivers differ in length.

Length may vary from 150 to 2,000 m, height from 5 to 30-40 m and the total length of hauling lines from 150 m up to 5,000 - 6,000 m.

Fishing grounds may be permanent, temporary or irregular. Permanent grounds are fished all the year round, (except close seasons) with from 20 to 30 sets per day. Temporary grounds are fished during 1-1½ months.

Permanent and temporary grounds are equipped as a rule with appropriate means of mechanisation. The area has houses for fishermen, shops, canteens, dispensaries, recreation and reading rooms and schools for children.

After stowing the net and lines on board, the seine boat is taken in tow by a towing cutter, with a skiff loaded with signal lanterns or flags. At the place of operation a seine is set across a river for about two-thirds of its width, as shown in Fig. 2, leaving a third of the

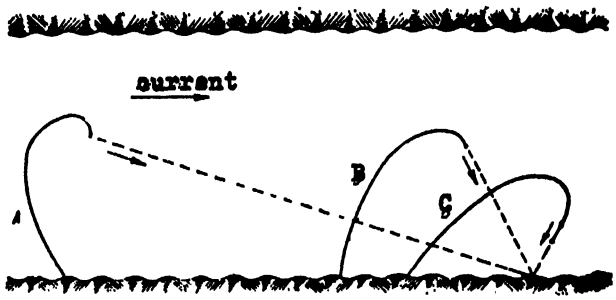

Fig. 2. Position of a beach seine at different stages of towing. (A) Shooting commences. (B-C) Positions as tow wing is towed to the bank.

width free. The cutter than makes for the beaching place, paying out a towline on its way.

When hauling commences, the line is first hauled at 70-80 m per min but, as the wing approaches, speed is reduced to 10-12 m per min. The shore bridle is attached to a block which travels on a wire as the net is carried downstream to the hauling point. There both wings are hauled together. The complete net can be hauled by the winch. The fish are removed through a special slit, on one side of the bag.

During hauling the towline and wing are stowed on the seine boat ready for a new operation.

The tow cutters are 8-12·5 m long—have draught of 0·5 to 0·8 m—and are powered with 6 to 15-hp engines. On the lakes the horse-power is increased to 20-30 hp (Fig. 3).

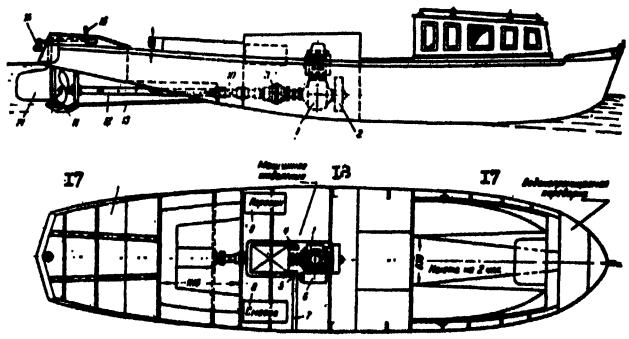

Fig. 3. Small-sized towing cutter. (1) Internal combustion engine. (2) Fly-wheel. (3) Reversing clutch. (4) Suction pump. (5) Discharging pump. (6) Muffler. (7) Exhaust pipe. (8) Lubrication. (9) Kerosine tank. (10) Screw shaft (11) Propeller. (12) Deadwood pipe. (13) Metal "ski" (14) rudder. (15) Tiller. (16) Tow hook. (17) Watertight bulkhead. (18) Engine room.

To set the net, a self-setting seine boat (Fig. 4) is used on which the deck platform is slightly inclined

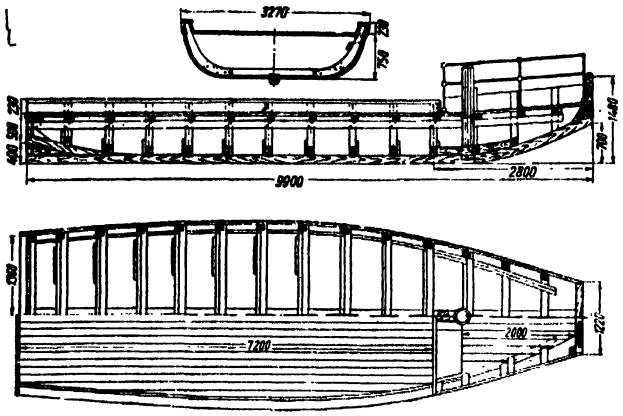

Fig. 4. Self-setting seine boat.

towards the stern. By flaking down the seine to a special pattern, it slips easily into the water while the boat is being towed (Fig. 5 and 6). A horizontal roller at the stern minimises wear and tear.

Fig. 5. Shooting a seine from a self-setting seine boat.

Fig. 6. Paying out the towline.

The first beach seine winch in the U.S.S.R. was invented in 1907 by a self-taught carpenter, Guzhayev, for hauling seines on the rivers of Siberia. The wide application for seine hauling started in 1923-1924. These winches did not differ much from those used in the building trade (Fig. 7).

New developments brought electric seine winches of LNR-1 type for river operation, and LNM-1 type for sea operation. The only difference is their traction force and range of hauling speeds which are 1,000 kg and 10-80

Fig. 8. Seine winch designed on tractor basis.

m per min for LNR-1 and 3,000 kg and 6-36 m per min for LMN-1 respectively.

The LNR-1 winch is shown in Fig. 9. Specific characteristics are (a) a wide range of hauling speeds by using

Fig. 9. Beach seine winch on the lower reaches of the Volga. This is a permanent installation.

a stepless frictional transmission, (b) two pairs of grooved warping heads to make the hauling process safe; (c) an automatic electric overload release control, and (d) indicators of hauling force and speed for greater efficiency.

Apart from the lines, the wings of seines are hauled ashore mechanically. An additional working line is attached to the footrope of the wing and is hauled while the wing is gathered on the deck of the seine boat.

Whereas previously from 100 to 120 people were engaged in shooting and hauling marine beach seines by hand, four or six men now do the same work.

In 1960-61 a special machine was developed to haul the wings of seines operated on sea beaches. The machine (Fig. 10) is a self-propelled tractor bogie on whose platform two vertical frictional driving drums are driven by

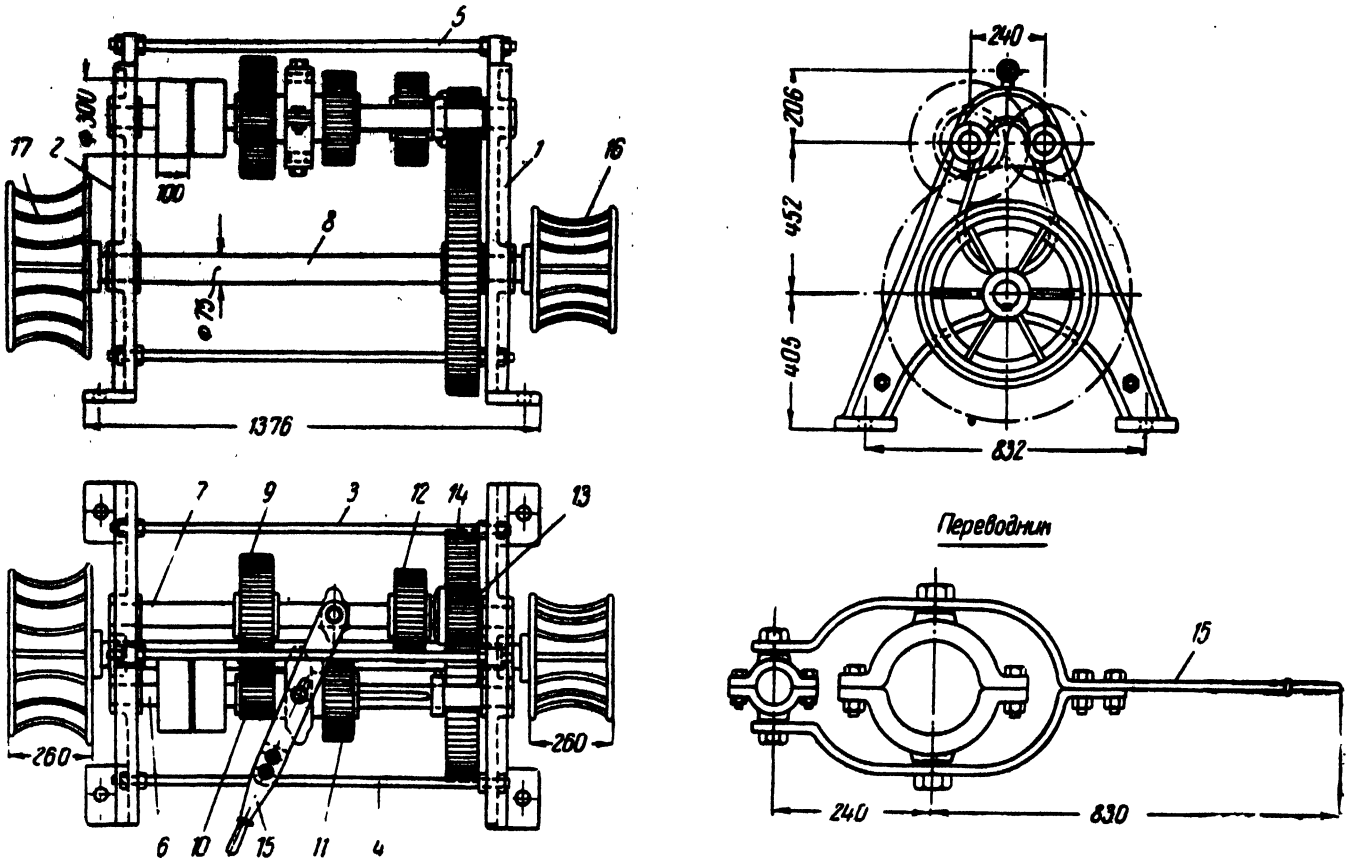

Fig. 7. Seine winch of Matveev's design. (1-2) Legs. (3-5) Stretcher bolts. (6) Driving shaft. (7) Intermediate shaft. (8) Working shaft. (9-14) Toothed wheel. (15) Change gear. (16-17) Tractor drums.

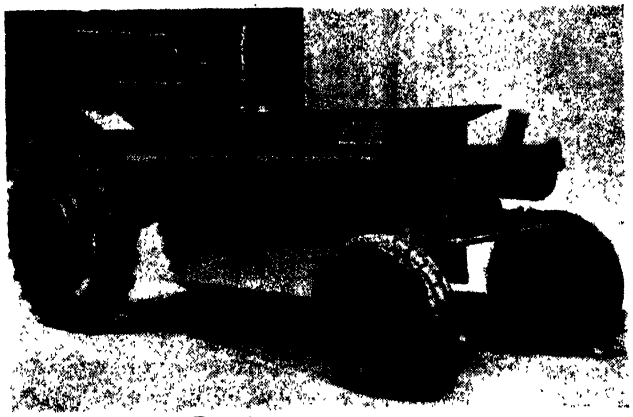

Fig. 10. Mobile seine hauler.

the tractor engine and the drive runs underneath the platform. Hauling can be done with the machine at standstill as well as while moving along the shore.

In river seining a special arrangement is made for releasing and hauling the shore wing. A steel rope is stretched between the initial point of setting and the stopping place ashore. A special snatch block with a hook runs along this steel rope. A shore-bridle called the hook-on line is fastened to the hook (Fig. 11). The seine moves with the current towards the stopper and it is necessary to retain it by making use of a brake arrange-

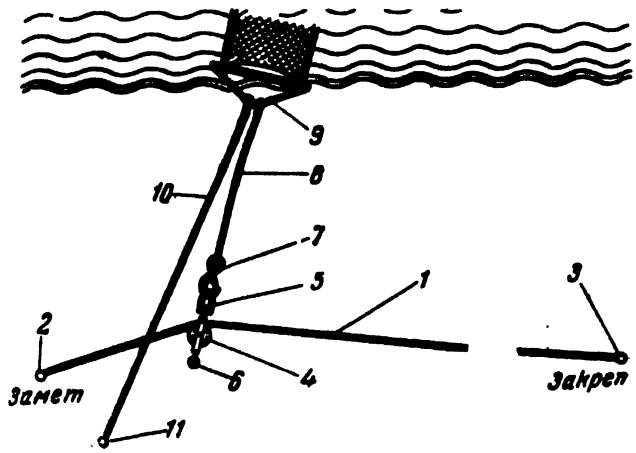

Fig. 11. Scheme of transferring a shore line (hook-on line). (1) Steel wire, (2-3) Anchoring points. (4) Metal block. (5-6) Cramp frame. (7) Hook. (8) Hook-on line. (9) Bridle. (10) Spare hook-on line. (11) Fixing peg.

ment or a fixing peg. The shore wing is then hauled from the stopping place to the landing spot by means of an endless rope, the arrangement of which is illustrated in Fig. 12.

Flaking and stowing of the seine on the seine boat is now done by special machines and devices. The NM-1 machine consists of three profiling drums and is installed

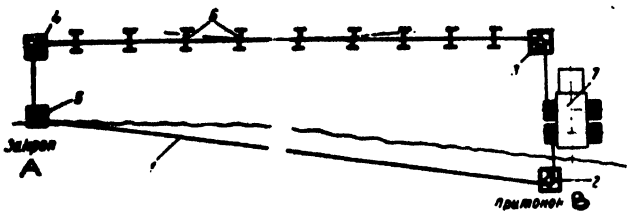

Fig. 12. Scheme of rope-way for drawing a shore line from the stopper to the place of stranding. (1) Endless rope. (2-5) Guiding rollers. (6) Supporting rollers. (7) Seine winch. (A) Stopper. (B) Start.

on a self-setting seine boat and, by guide rails, stows the seine along the deck platform. The main features are shown in Fig. 13 a and b. For stowing marine type beach seines other machines are applied, which usually consist of two vertical drums installed on the stern platform of the seine boat. The drums are driven electrically with the driving unit installed under the deck.

The above mechanisation is quite effective at stationary fishing grounds but on temporary and irregularly-

Fig. 13b. Machine for automatically stacking seine out of water on to boat ready for setting.

operated grounds would be less efficient. On such grounds the gear must be mobile and simple, cheap and easily manoeuvred, to ensure quick switch from one ground to another.

Two types of gear are applied at occasionally-fished grounds. These are: a hauling cutter in combination with

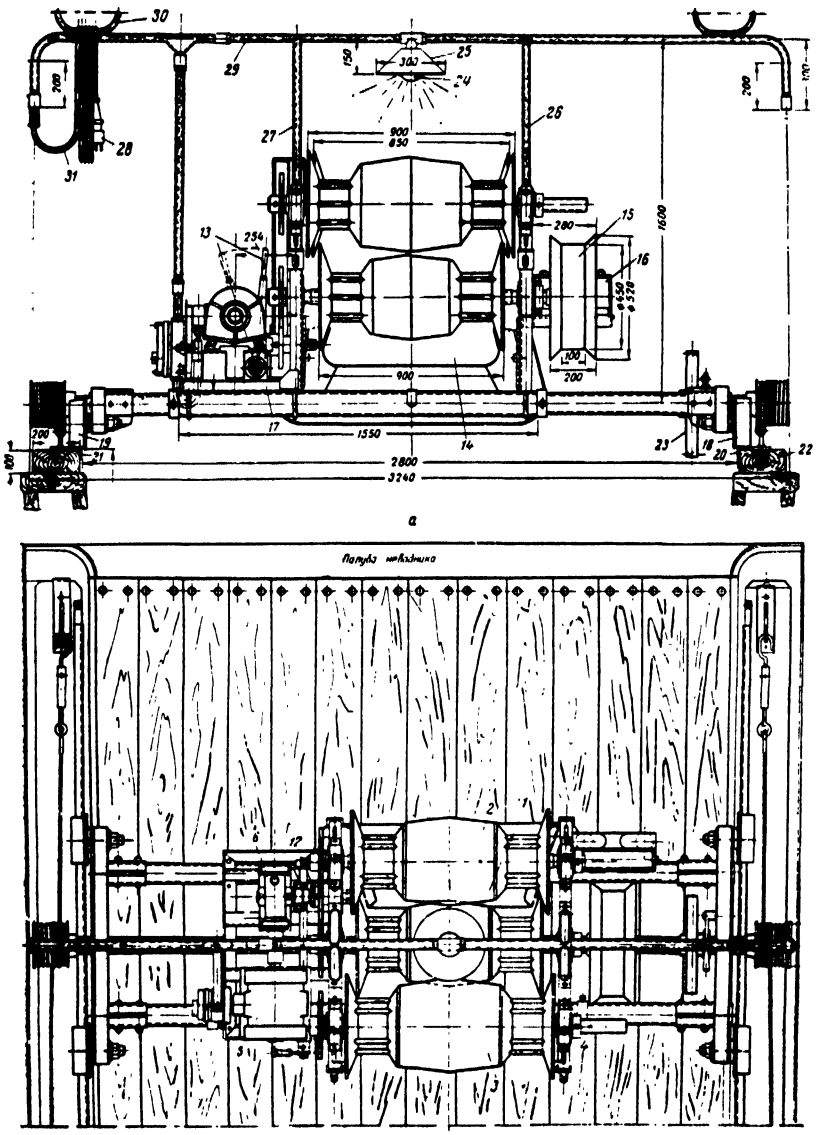

Fig. 13a. Seine-stowing machine. (1-3) Profiling drums. (4) Frame. (5) Electro-motor. (6) Reductor. (7-10) Star-wheels of the chain. gear. (11). Chain. (12) Tappet sleeve. (13) Adjusting handle of the tappet sleeve. (14) Gutter. (15) Gipsy head. (16) Roller. (17) Platform (18-19) Running wheels. (20-21) Guiding rails. (22) Bulwark rail. (23) Steering wheel. (24) Electric bulb. (25) Rejector. (26-27) Legs. (28) Pipe (29-30) Arcs. (31) Electric cable.

a self-setting seine boat and a motor seine boat. The winch cutter is a modified kind of 6-10 hp towing cutter with a winch installed at the stern and driven by the cutter's engine (Fig. 14). The hauling power of the winch

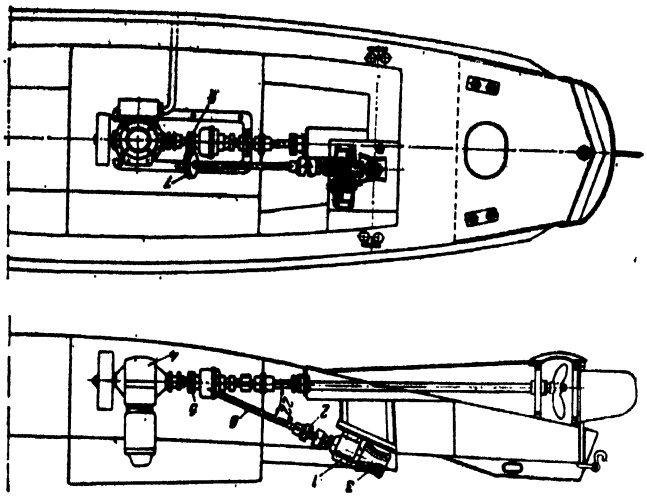

Fig. 14. Winch cutter.

is 750 kg; hauling speed 25 m per min. The draught of the cutter is only 0·5 m which allows the vessel to pass shallow rivers, streams and lakes. The helper boat is a small-sized self-setting seine boat for stowing, transporting and shooting the seine. This makes is possible to

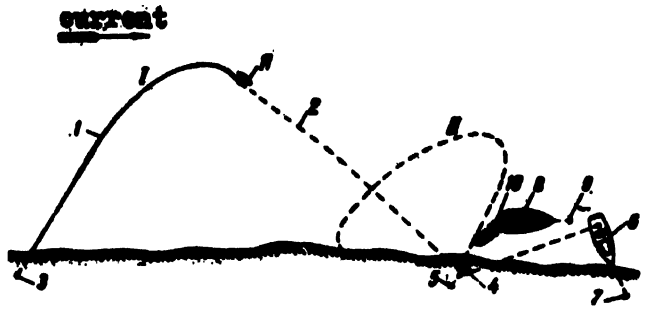

Fig. 15. Scheme of operation of a seine on an occasional fishing ground. (1) Seine. (2) Towline. (3) Fixing peg. (4) Snatch block. (6) Winch cutter. (7) Mooring anchor. (8) Self-setting seine boat. (9) Anchor for fixing a seine boat. (10) Wing of a seine which is stowed. (11) Lantern boat.

transfer fishermen from one ground to another quickly.

The team operates as follows: before shooting, the cutter lands two men (with snatch block gear) and they secure the necessary shore installation with anchors. When the net has been run out, the towline is passed through the snatch block to the winch drum of the cutter which is anchored in the position shown in Fig. 15, and hauling begins. Then they go to the next operating ground. A team can operate six to eight sets per day, whereas without such mechanisation 9-10 fishermen make only one or two sets per day.

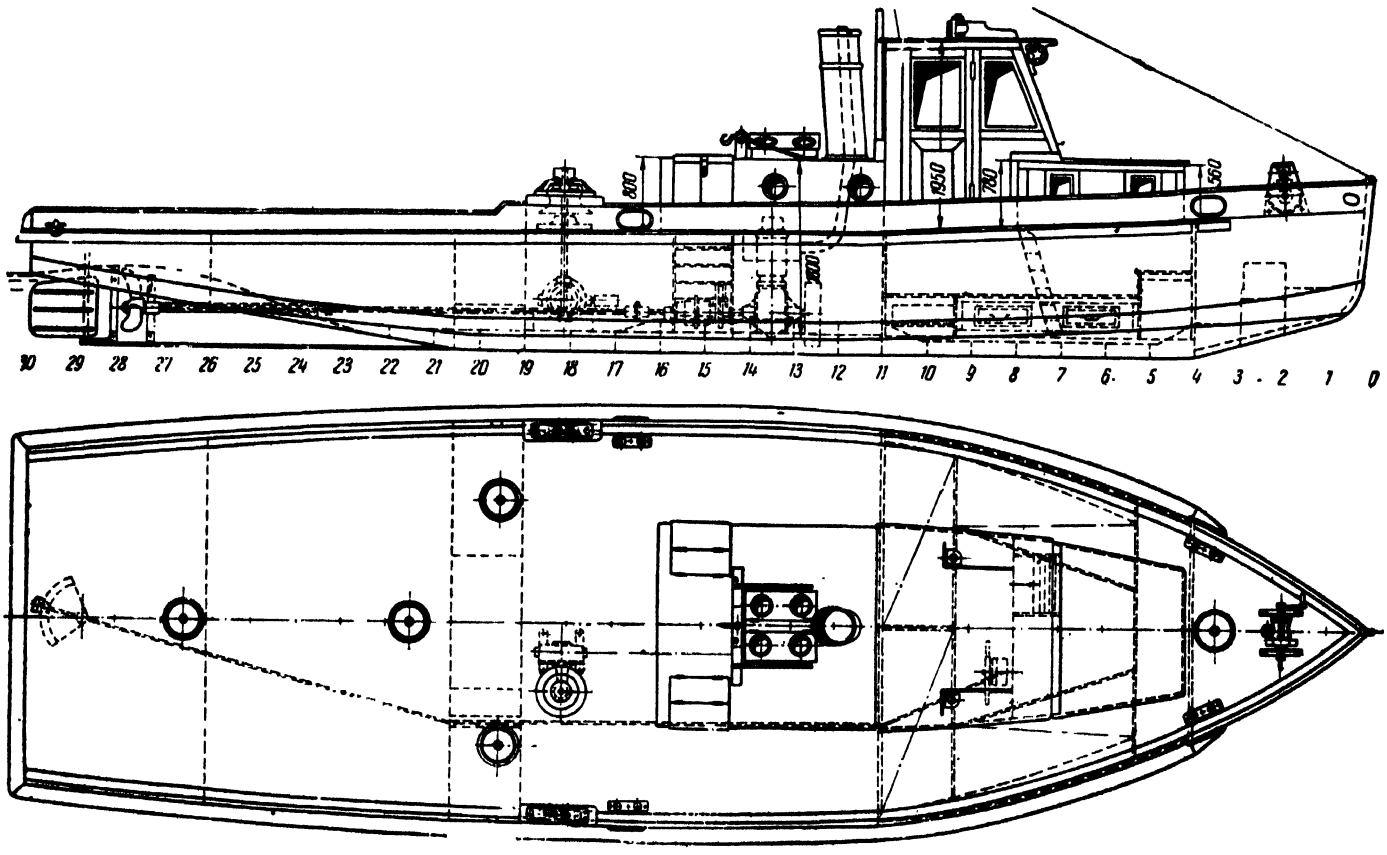

Fig. 16. Motor seine boat.

Around 1940 it was suggested that it would be more practical to combine on board one vessel the advantages of the tow cutter and the self-setting seine boat as well as the hauling devices. As a result, a motor seine boat was designed as shown in Fig. 16. The vessel has a displacement of 10 tons for a length of 13·5 m and 0·75 m draught. It is powered by a 15-hp engine and develops a speed of eight to nine km/hr (4·5-5 knots). The 1,000 kg at a

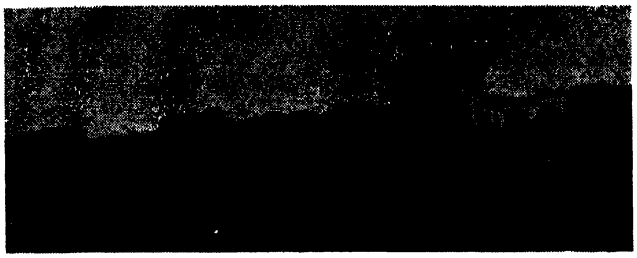

Fig. 17. Motor seine boat with a seine-stowing machine of 1953 model.

hauling speed ranging from 15 to 40 per min (50-130 ft/min). Apart from the winch they are also equipped with a seine stowing machine of NM-1 type (Fig. 17). Such vessels allow full mechanisation of seining and complete mobility from one fishing ground to another.

Discussion on Deck Machinery and Control

Mr. E. A. Schaefers (U.S.A.) Rapporteur: Lerch (Paper No. 64) indicates that progress in fishing gear development has been slow. Great strides have been made, however, in the application of power and mechanisation on board fishing vessels. Mechanisation for handling king crab pots in Alaska, as described by Allen, has been largely responsible for the economic success of a fishery which utilises a passive type of fishing gear. King crab fishing is so highly mechanised that the most recent and largest king crab fishing vessel in Alaska, which is 159 ft in length, operates with a crew of only four men. Kuraptsev indicates that although driftnet fishing operations for herring have lagged behind other fishing methods with regard to mechanisation, Soviet gear technologists have recently developed mechanical deck equipment which has allowed for reducing the number of crew members while increasing the hauling and handling speed. This equipment includes net haulers, net shaking machines and special mechanisms for hauling the bridles and stowing the warp. The high degree of automation and extensive use of centralised controls will enable the 99-ft English sterntrawler *Ross Daring*, when launched, to operate with a total of five men, whereas a conventional sidetrawler of comparable size would need ten men on deck alone. The recently launched highly mechanised 83-ft United States combination sterntrawler-purse seiner *Narragansett*, is already operating in the trawl fishery with a total crew of only four men. New hauling appliances for beach seines, as described by Torban, have replaced the manual labour which formerly performed these operations. Consequently, this is no longer one of the most laborious types of fishing methods. Lerch also indicates that hydraulic power has played an important part in increasing fishing efficiency, especially in the United States fisheries. He divides hydraulic systems for fishing vessels into low pressure, 200-550 psig, medium pressure, 1,000-2,000 psig and high pressure, 2,000-5,000 psig. He outlines the various systems and gives particular attention to controls. In the United States the medium pressure system is favoured. These hydraulic systems make possible multiple and remote controls and the advantages of these are clearly pointed out, with examples of hydraulic gear handling machinery such as gillnet reels, crab pot haulers, and various power units on modern tuna and salmon purse seiners. He emphasises that the most important factor for the protection of long life of hydraulic pumps, motors and control valves, is maintaining clean oil at all times. It has been my experience that it is well worthwhile to assign one individual the specific task of ensuring that no dirt enters the system during installation and that no dirt enters the system when oil is added later. If a hydraulic system starts out with dirty oil it will never function properly. If it starts out with clean oil, there is no reason to expect malfunctioning.

I am sure we are aware that increased mechanisation is the key to the survival of commercial fishing as a business proposition. But we must ever be mindful that we do not get technologically ahead of the capabilities of man to direct the wonderful advances made possible through technology. There appears to be little danger of this at the present time. Pain's paper on centralised control in trawlers covers such items as rationalising the wheelhouse, navigational controls, automatic steering and the automation of propulsion and auxiliary diesel engines. This subject was discussed at the World Fishing Boat Congress in 1959 and it would be interesting if we can now have some reports of firsthand experiences regarding the use of much of this equipment.

Dr. Schärfe (Germany): The whole objective of centralised control and improved deck machinery is to make fishing pay better. Therefore, we must keep a sharp eye on economic factors. At the last Fishing Boat Congress the late Commander Hardy suggested that the cockpit of an airliner might be a good example of how to design the ideal wheelhouse for a trawler. There is, however, a danger that the skipper might be overworked if asked to do too much in the way of control. It might therefore be better to leave a part of the tasks with the engineers, the radio operator and an eventual sonar operator. There was also the danger that the centralised control panel might take space in the wheelhouse which might be used more profitably in other ways. A compromise for the large trawler would be to distribute the tasks. Centralised winch control appeared to be a very sound idea but the factors of cost and the working power of the skipper should also here be taken into consideration. The basically good idea of centralised control should not be overdone—they should centralise with sense.

Commander H. Pain (U.K.): "Centralisation with sense" is a very good catch phrase. What his company meant by centralisation was only the gathering together of those instruments and operations in the most convenient place for the best operation by the right number of men to achieve the prime objective. This applies to the biggest ship in the world as well as to the smallest. His plea was that it was useless for the automation companies to be given the task of automating a ship when the ship's design has been already finalised. They had to do this on a number of occasions and the result has

not been very happy. He recommended the company come in for consultation with the owners, the yard and the naval architect at a very early stage when the ship's specifications were being drawn up. The *Narragansett*, the *Ross Daring* and other ships had proved that if this concept was applied they would get a more efficient and more economical class of vessel. A very important factor was the human engineering problem. They might have to produce a newer type of skipper; "fishery control officer" might be the better term. Skippers were being faced more and more with a mass of highly scientific "black boxes" and many of those he had met were rather frightened of them. He thought, however, that "Big Brothers" as he termed them, could help the fishing industry considerably. I suggest that most owners, builders and architects know some of the answers some of the time but no one class of people know all the answers even half the time. If you can go to the big organisations and are prepared to consider the ship as a piece of system engineering then you can secure advantages. If it is considered from the beginning as an engineering problem, the systems engineer can give results.

Mr. Lusyne (FAO): Apart from asking too much from the skipper in this mechanising and controlling I see another difficulty, which is the problem of the skipper obtaining the information necessary to exercise control. The skipper must consistently be informed of what is going on. At the present time, without mechanisation, the skipper sees the warps closing and opening and that gives him vital information. If he is locked up in the wheelhouse, however, he must depend entirely on machines for the incoming information he needs. If these fail to function properly, as machines sometimes do, he will cease to get the information he wants.

Dr. Heinsohn (Germany): I agree with other speakers in respect of not overdoing centralised controls. On deck machinery they had heard much about hydraulics but he would like to mention electricity. In many cases it did not matter whether hydraulics or electrics were used. Many people had a horror of electricity—he had too—but when he thought of high pressure hydraulics it was just as bad. The stress put on absolute cleanliness meant that they had to have experts on that as well as with electricity. Where you can use your prime source of energy for different purposes it may be more favourable to use electricity rather than hydraulics. On big bottom trawlers you use your winch power also on propulsion and if you come to very modern achievement you use your winch braking power to feed it back into the propeller. Shooting a big trawl in deep water consumes a lot of energy which is wasted on the brakes which have constantly to be replaced at heavy cost. It is therefore, quite useful to look for devices which feed this otherwise useless power into the propeller. This is possible where prime movers for winch power are derived from the propeller shaft which is the normal case today. It is not possible to do this with high pressure hydraulics because they are sensitive to over-speeding. With electric power this is quite easily possible provided you have the correct gear on the winch. I learned the other day that it is also possible with low-pressure hydraulics and that is a fact that should be taken into consideration. As regards centralised control, it looks impressive and does save a good deal of space. But with echo sounders and radar features developing as they do, it might be desirable after a few years, to install new fittings. That may then be difficult. Therefore, it might be better to accumulate all your "black boxes" around the bridge and in the long run it would be more practical.

Mr. J. G. Fontaine (France): In view of the complexity of automation and the need for the skipper to supervise so many things at the same time, guards should be provided against possible damage. Automation is really an industrial question. It should be possible then, in view of the automatic control of engines, to provide some equipment which would indicate any dangerous rise in temperature and would also cut the engines out. In that way accidents might be avoided and the damage, if any, repaired.

Mr. R. F. Allen (U.S.A.): The original reason for the remote controlling of various winches on big tuna vessels was for swinging and lifting the main boom, for pursing the net and for brailing. We, therefore, planned to locate the operator in the position where he could see all phases of what was going on, yet not be working on the deck itself. The safety feature of this is most important and by using hydraulic drives on some of these winches we have been able to obtain instantaneous stopping and starting of them from at least one position. In other cases we have achieved the same objective with duplicate control points. This is most important where gypsies are used and where men have to face the hazard of getting their hands in the winch or being pulled up into the power block in the case of seine haulers. Experience thus far shows we have had no maintenance difficulties or failures of equipment because of the remote location of the controls. On some of our modern tuna seine winches the controls evolved for clutch and brake engagements are of such a nature that the operator from a distance of five metres can feel the pressure applied to the brake which is accomplished by getting the resistance off the valve in the same way as is done with aeroplane controls. This is a very desirable characteristic particularly where you are using a friction device as a means of accelerating a load or stopping a load. Hydraulic drives on these vessels have proved to be very satisfactory for minimising horsepower requirements on deck gear because all operations are performed in such a manner that maximum pull does not come at the time of maximum speed requirements. The system of shifting the speed through hydraulics, therefore, is limited to the horsepower requirements of the gear. Remote control can be carried round the deck to activate the power block. In the Pacific Northwest, salmon seiners, operating with seven men, have been able to eliminate one man because they have electrical controls on the hydraulic system. This enables the captain of the boat to handle the stacking of the net and eliminates having a man on deck at the time. This is a simple device and it has eliminated about 15 per cent of the manpower on the vessel.

Mr. W. W. Carlson (U.S.A.): When we built the *Narragansett* we did so not only for the benefit of the developed countries but with an eye on the developing countries where trained personnel is presently a problem. We felt that one reasonably well-trained man could run the whole thing.

Mr. Schaefers, in summing up, after mentioning the points of each speaker, said that the general tone brought out during the discussions was that many developments contributed to and led up to centralised control and automation which in turn led to increased efficiency. This has been particularly so in the United States where operations, in many fisheries, are now carried out with fewer people and even includes those trawl fisheries where it is not normal practice to process the catch on board. He also stressed that more effort should be devoted to automation of the entire fishing and ship operation, rather than just getting the fish aboard.

A Comprehensive Echo Sounder for Distant-Water Trawlers

Abstract

Operation of conventional fish-detection echo sounders in bottom trawling has indicated some shortcomings, for example, the inadequate range of detection of single fish, the missing of echoes due to aeration of the transducers, the strain on the operator resulting from the transient nature of the cathode-ray tube expanded display, the lack of memory in this display over the period of a tow and the movement of displayed echoes due to the motion of the ship. The improved techniques of the Humber Fish Detection System largely overcome these difficulties. It embodies a high-power transmitter (8 kw), a narrow-beam transducer lowered beneath the vessel on a shaft and two sea-bed-locked scale-expanded displays which indicate fish close to the sea bed. The transducer gives an acoustic beam 13° wide (between 3dB points) and 8° wide (in the fore/aft direction). One display employs a cathode-ray tube with a continuously-bright trace and the other is a triggered mechanical recorder which gives a permanent record on dry paper. The transmission interval is determined by the range required, for example, 0·6 sec for 240 fm. Echoes from fish near the sea bed are stored on a magnetic drum recorder and are replayed many times on to the cathode-ray tube whilst awaiting the next set of echoes. The stylus on the triggered recorder is initiated by the sea-bed echo and crosses the paper 6 in wide in 0·01 sec (equivalent to 4 fm range).

Un sondeur par écho comprehensif pour les chalutiers de haute mer

Résumé

Des imperfections se sont révélées dans le fonctionnement des sondeurs par écho pour la détection pour le poisson seul, l'absence d'échos causée par l'aération des transducteurs, la tension chez l'opérateur résultant de la nature transitoire de l'image dilatée du tube à rayons cathodiques, le manque de mémoire de ce système pendant une période de remorquage et le mouvement de ces images d'échos dû au déplacement du bateau. Les techniques améliorées du système de détection de poissons Humber surmonte en grande partie ces difficultés. Il comprend un émetteur à haute puissance (8 kw), un transducteur à rayon étroit, abaissé sous le bâtiment sur une perche, et deux images à échelle étendue et fixées vers le fond qui indiquent le poisson proche du fond. Le transducteur donne un rayon acoustique large de 13° (entre les points 3 dB) et de 8° (dans les directions avant/arrière). Une image emploie un tube à rayons cathodiques avec une trace continuellement lumineuse, et l'autre est un enregistreur déclenché mécaniquement qui donne un rapport permanent sur papier sec. L'intervalle d'émission est déterminé par la distance désirée par exemple, 0,6 seconde pour 440 m. Les échos des poissons se trouvant près du fond sont déposés sur un enregistreur cylindrique magnétique et sont rejoués de nombreuses fois sur le tube à cathodes en attendant le prochain lot d'échos. Le style, sur l'enregistreur est amorcé par le fond de mer et traverse le papier au rythme d'une largeur de 15 cm en 0,01 seconde (égal à une étendue de 8 m).

Un ecosonda completo para los barcos de pesca de altura

Extracto

El empleo de los ecosondas de tipo convencional para detectar la pesca en el fondo del mar ha revelado ciertas deficiencias, como es por ejemplo el inadecuado poder de detección con respecto a los peces individualmente, la falla de los ecos a causa de la aereación de los transductores, el cansancio que padece el operario debido al carácter transitorio de la presentación ampliada del tubo de rayos catódicos, la falta de memoria en esta unidad de presentación durante el rastreo, y el desplazamiento de los ecos presentados por razón del movimiento del barco. Merced a las técnicas más avanzadas del Sistema Detector de Pesca Humber se han logrado vencer estas dificultades. Está provisto de un transmisor de gran potencia (8 kw), un transductor de haz estrecho que se hace descender por debajo del barco en un tubo y dos unidades de presentación a escala ampliada dirigidas al fondo del mar, que indican cuándo la pesca se encuentra próxima al lecho del mar. El transductor emite un haz acústico de 13° de ancho (entre puntos de 3 dB) y 8° de ancho (en la dirección de proa y popa). En una de las unidades de presentación se emplea un tubo de rayos catódicos con un trazo continuamente brillante, y la otra unidad es un aparato registrador mecánico de maniobra independiente que da una indicación permanente sobre papel seco. El intervalo de transmisión depende del alcance requerido, por ejemplo, 0,6 segundo para 440 metros. Los ecos causados por los peces cerca del fondo del mar son memorizados en un registrador de tambor magnético y son reporducidos muchas veces en el tubo de rayos catódicos mientras se espera que llegue la próxima serie de ecos. La aguja del registrador de maniobra independiente empieza a funcionar por el efecto del fondo del mar y atraviesa el papel de 15 cm de ancho en 0,01 segundo (equivalente a un alcance de 8 metros).

by

G. H. Ellis, P. R. Hopkin and R. W. G. Haslett

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G. H. Ellis

P. R. Hopkin

R. W. G. Haslett

EXPERIENCE in the Arctic cod and haddock fisheries aboard Humber trawlers fitted with earlier types of echo sounder for fish detection, has emphasised some shortcomings in the performance of these equipments. For example, when used in conjunction with a conventional recorder, the cathode-ray tube display had to be adjusted manually to indicate echoes from fish near the sea bed. In order to obtain adequate information from the equipment, the cathode-ray tube must be observed for periods of hours, whether searching for fish over a wide area or determining the most profitable section of an actual tow. There was considerable strain on the operator resulting from the intermittent nature of the display (which is, in fact, a single flash on an otherwise blank screen), and the necessity of continuously manipulating the depth control when operating the equipment over a sea bed of widely varying depth.

To make a reasonably accurate assessment of the potentialities of a particular fishing ground, the echo sounder

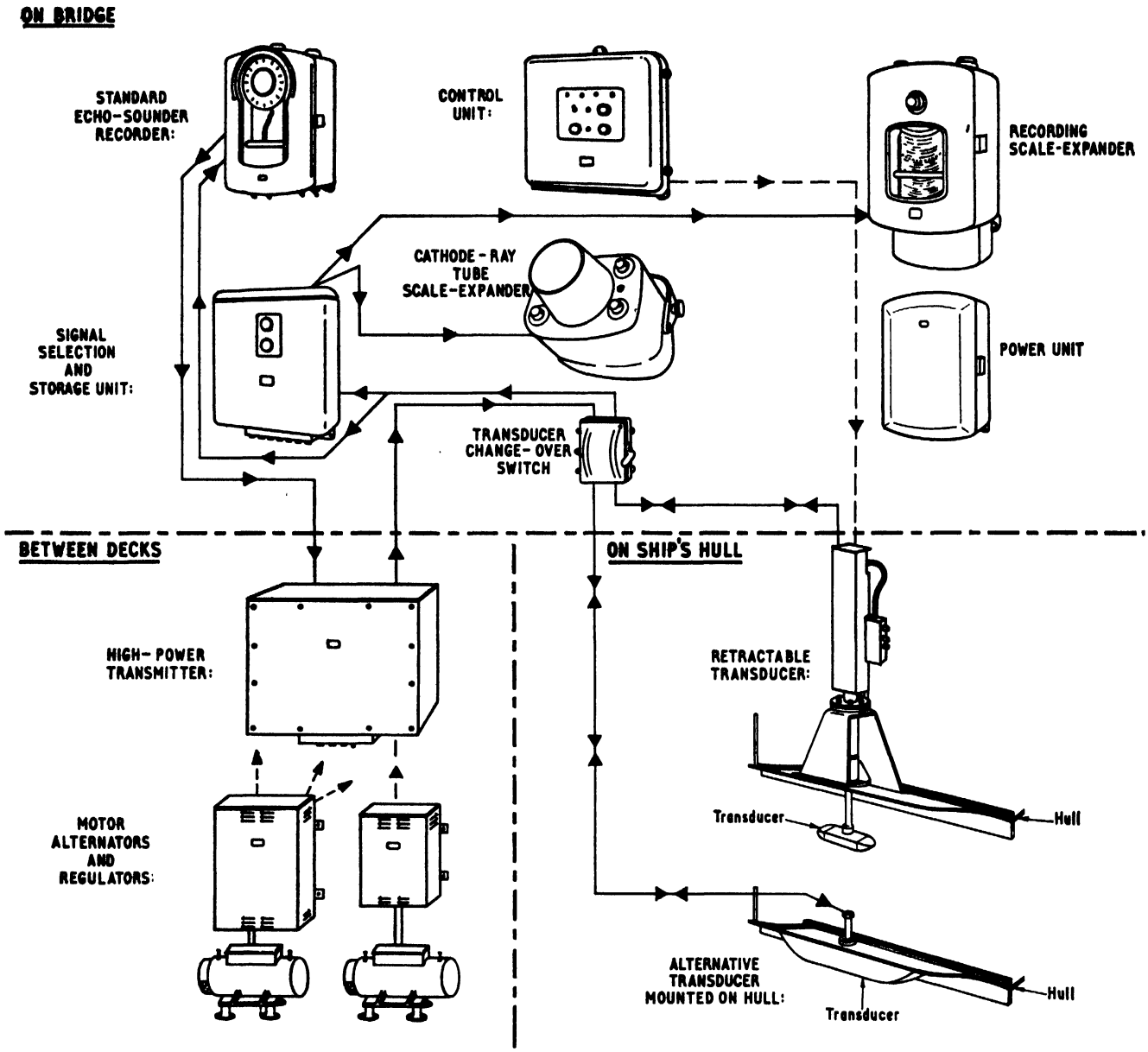

Fig. 1. The complete Humber Fish Detection System.

must be capable of detecting a single fish of minimum catchable size at the trawling depth. Catching rates in excess of 150 baskets of cod per hour have occurred when the fish have been spread out singly, close to the sea bed throughout the whole of the tow. The range of detection of a single fish on existing echo sounders aboard Humber trawlers falls well short of the maximum trawling depth of 280 fm; in some cases the limit of detection was about 125 fm for the smallest cod which does not pass through the net.

In rough seas which may still permit trawling, the operation of any echo-sounding equipment using hull-mounted transducers is seriously impaired by aeration.

The Humber Fish Detection System has been designed especially for use on distant-water trawlers to give improved performance in the above respects.

The Humber Fish Detection System

In the new equipment (Fig. 1), a high-power transmitter operating at 30 kc/s delivers a peak power of 8 kw in pulses of $\frac{1}{2}$, 1 or 2 millisecond duration to a 6λ by 4λ transducer which is mounted 2 ft below the skin of the vessel on a remotely-controlled retractable shaft. In addition, a similar transducer is mounted on the hull in the normal way for use when steaming.

Received echoes may be observed on three different types of display, one of which is a conventional echo-sounder recorder with "white-line" facility. The other two displays (Fig. 2) are locked to the sea-bed echo irrespective of the vertical motion of the ship or changes in depth and, in consequence, may be greatly expanded to show echoes from fish near the sea bed. The required echoes are selected by a time-gating circuit and stored

on a magnetic recording drum rotating at 3,000 rpm (Hopkin 1963). The system is switched to display the echoes by the arrival of the sea-bed signal.

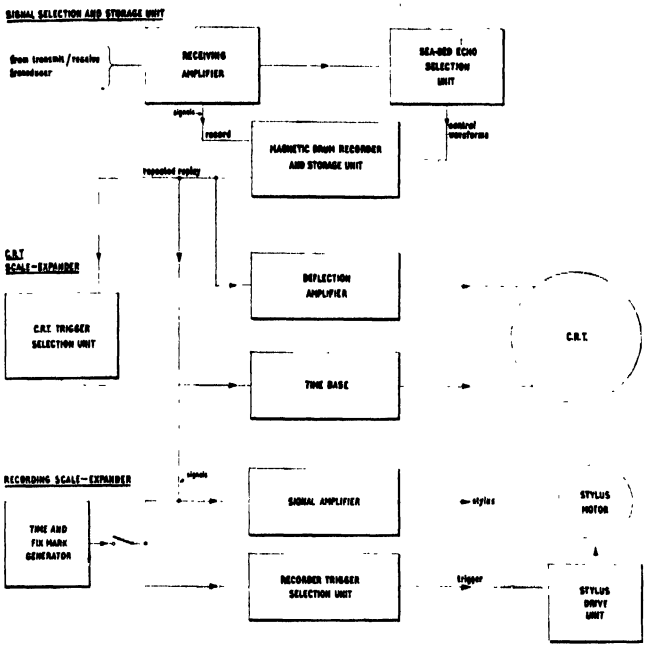

Fig. 2. Block diagram showing the receiver and sea-bed locked displays.

The stored signals are used in two ways:

First, the stored echoes are replayed many times to give a continuously bright picture on a seven-inch diameter cathode-ray tube scale-expander (Hopkin 1963). With the usual transmission interval of 0·6 second, about 27 repetitions are possible before the arrival of the next set of echoes. The time base may be set to display echoes from the bottom four- or two-fathom section of water.

Secondly, the stored signals are fed to a recording scale-expander (Haslett 1962). This is essentially a triggered rotating-arm recorder of high precision, producing a permanent record of the stored signals on dry paper 6 in wide. The leading edge of the sea-bed echo appears as a thin straight line on the right-hand side of the record. The stylus, which is triggered once per transmission period, crosses the paper in 0·01 second, producing a record of echoes from the bottom four-fathom section of water.

Performance at sea

Prior to the manufacture of the Humber Fish Detection System, a prototype model was used on board the Hull trawler *Westella* for a period of two years during fishing voyages to the Barents Sea, and off Iceland and Norway.

With this equipment it was found that the maximum detection range of a single cod is increased to 250 fm. When towing in a heavy swell, the "missing" due to aeration is noticably reduced by the use of the lowered transducer.

The sea-bed locked displays operate reliably over the complete range of trawling depths on various types of sea bed. With the increased time of display of each set of echoes, and improved signal/noise ratio (Fig. 3), the cathode-ray tube scale-expander traces are much easier to interpret. The large diameter tube, the increased brilliance obtained by the repeated replay system, and the sea-bed locked display, allow the screen to be observed from a distance without strain.

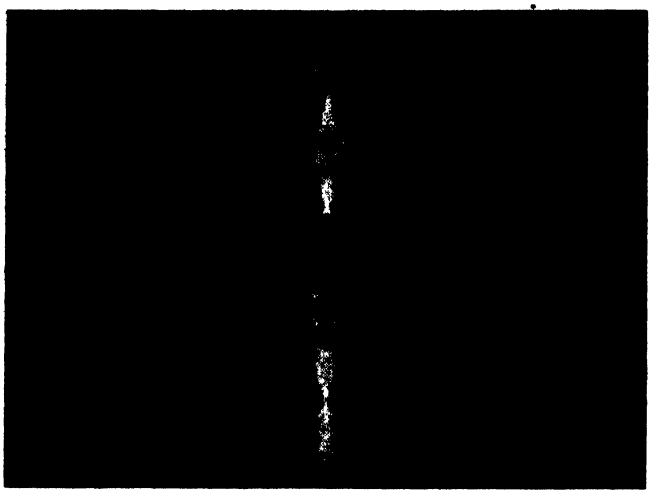

Fig. 3. With increased time of display of each set of echoes and improved signal/noise ratio, the cathode-ray tube scale-expander traces are much easier to interpret.

The record of the horizontal and vertical distribution of fish close to the sea bed, provided by the recording scale-expander (Fig. 4), permits a considered assessment of the most profitable section of a tow. Large increases in the catching rate have been obtained when tows were modified to trawl more frequently through the positions of maximum density of fish below headline height, as shown by the recording scale-expander chart of the previous tow. This chart also allows the skipper to use his own judgment in the assessment of the best sections of tows made whilst he is not on the bridge.

After some experience had been obtained with the interpretation of the recording scale-expander chart, an observer (other than the skipper) was asked to make estimates of the expected catch by the examination of the chart at the end of each tow, before the net was hauled. One hundred and fifty estimates were made in depths of water between 50 and 200 fm, during six fishing voyages over a period of one year; and 70 per cent of the actual catches were within 40 per cent of the estimate, the mean error being 38 per cent. The most accurate estimates were made when all recorded fish echoes were below headline height. There was a tendency to over-estimate at short range.

After a total period representing over 50 trips and involving several sets, it can be said that this equipment is proving very successful, as an aid to trawling.

Acknowledgements

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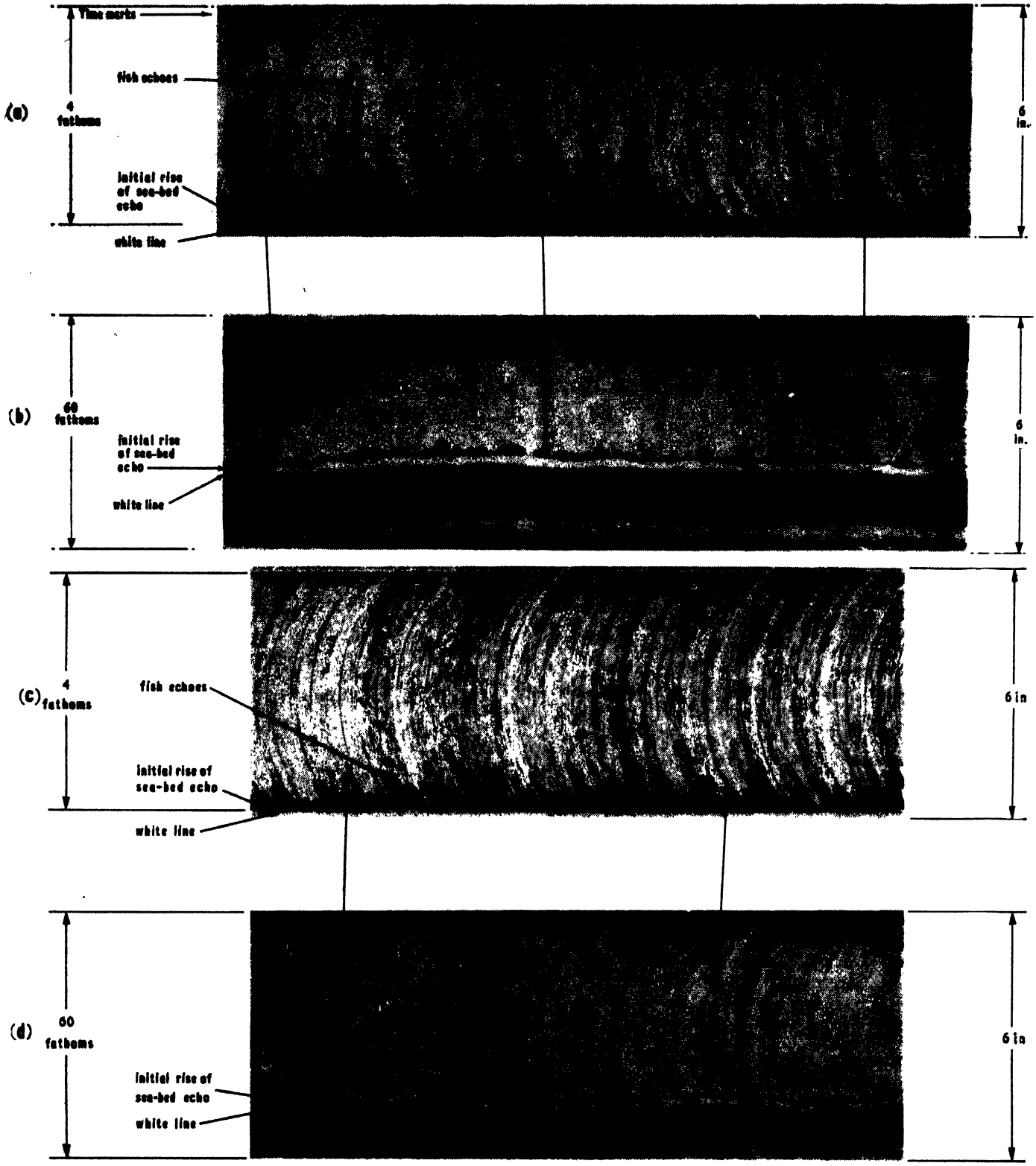

Fig. 4. Typical charts obtained with the recording scale-expander, compared with corresponding normal echo-sounder charts taken at same time. Numerous fish-echoes are seen above the sea-bed echo; some points corresponding in time are indicated:

(a) scale-expander chart
(b) normal chart
} *depth 100 fathoms; fish—cod and haddock; 30 baskets/hour.*

(c) scale-expander chart
(d) normal chart
} *depth 70 fathoms; fish—haddock; 70 baskets/hour.*

(*M.T.* Westella *trawling at 4 knots, July 1960*)

Sector-Scanning Sonar for Fisheries Purposes

by

Abstract

Research at the Electrical Engineering Department of the University of Birmingham has led to the development of electronic sector-scanning sonar systems which can be valuable in fisheries work. Early experiments at sea demonstrated that such a system was very effective in delineating schools of fish either ahead of the ship or below it. The latest development in the equipment itself, its performance (particularly with respect to angular resolution), and its manner of use have led to the possibility of the accurate detection and location of fish very near to the sea bottom. Moreover, the receiving part of the equipment has been developed in a universal form which can be used with any acoustic frequency within a wide range, and thus without difficulty and with great saving of cost can provide a general-purpose sonar suitable for high resolution at short ranges or lower resolution at longer ranges, using different transducers but the same electronic system. It seems clear that the equipment is now ready for commercial exploitation in fisheries.

Balayage de secteur en sonar pour la pêche

Résumé

La recherche dans le Département Technique Electrique de l'Université de Birmingham a mené au développement de systèmes sonar de balayage électronique de secteur qui peuvent être valables dans la technique des pêches. Des expériences conduites en mer ont démontré que ces systèmes sont très efficaces pour tracer les bancs de poissons repérés en avant ou sous le bateau. Les derniers développements dans l'équipement luimême, son fonctionnement (respectant particulièrement la résolution angulaire) et les modes d'emploi ont mené à la possibilité de détecter et de localiser précisément les poissons se trouvant près du fond. Le récepteur de l'équipement a été développé sous une forme universelle de telle sorte qu'il peut être utilisé dans une large gamme de fréquences acoustiques. De cette façon on peut facilement et à peu de frais construire un sonar à but général qui convient pour une haute résolution à courte portée ou une basse résolution à longue portée, utilisant des émetteurs différents dans le même système électronique. Il semble que l'équipement est maintenant prêt pour l'exploitation commerciale dans les pêches.

El sonar de exploracion por sectores en la pesca

Extracto

Las investigaciones realizadas en la Facultad de Ingeniería Eléctrica de la Universidad de Birmingham han culminado en la fabricación de aparatos de sonar electrónicos de explotación por sectores que pueden ser muy valiosos en la pesca. Los primeros experimentos realizados en la mar demostraron que tal sistema es muy eficaz en la localización de cardúmenes delante o debajo del barco. Los más recientes adelantos en el material, su rendimiento (particularmente con respecto a la resolución angular) y la manera de usarlo han creado la posibilidad de encontrar y localizar con exactitud cardúmenes muy cerca del fondo. Además, la parte receptora de los aparatos se ha perfeccionado de forma universal que puede emplearse con cualquier frecuencia acústica en una gama muy amplia y con ello, sin dificultad y con gran economía de coste, constituye un sonar de múltiples usos a propósito para lograr gran resolución a poca distancia o resolución más baja a distancias mayores empleando diferentes transductores pero el mismo sistema electrónico. El material está ya listo para su explotación en la pesca industrial.

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EXISTING sonar, asdic, or echo-sounding equipments which are commercially available always use a single fixed beam, usually several (or many) degrees in width. In the case of equipments designed to use the beam in an approximately horizontal position, provision is made for swinging the beam by rotating the transducer bodily. If it is desired to scan a sector, then it is necessary to allow time for a pulse to travel out to the maximum range and for echoes to return to the transducer before the beam is rotated to its next position. Since the speed of sound in water is very low, about a mile a second, it clearly takes a great deal of time to search a large sector effectively. A compromise has to be made between beamwidth and speed of search. Generally the beamwidth is of the order of 5°, which not only gives a rather slow rate of search but is quite unsuitable for detecting fish near the sea bottom because of the high background of reverberation which such a large beamwidth produces.

Electronic sector-scanning sonar (Figs. 1, 2, 3, 4) overcomes these difficulties. The way in which it works is shown in Fig. 1. A relatively wide sector, say about 30°, is illuminated by a pulse transmitted from a transducer having a wide beam. The receiving beam is made very narrow, say 1°, and by electronic means is swept rapidly from one side to the other of the sector, the process being continuous and repetitive; the time required for one complete sweep is equal to the duration of the transmitted pulse. This means that all directions within the sector are sampled before the pulse has moved its own length through the water. In other words, the whole width of the sector is virtually simultaneously examined; and by the time the pulse has reached its maximum range, information has been received from all points in the sector. It is thus possible to have the receiving beam as narrow as may be desired without prejudice to the rate of search. The method of displaying the information is also indicated in Fig. 1. The most effective display seems to be the B-scan on a cathode-ray oscilloscope; this is a display in which range and bearing are used as rectangular co-ordinates, the range time base being synchronised with the movement of the pulse as it passes through the water, and the bearing time base being synchronised with the electronic sweep of the receiving beam. Any echoes received from targets within the sector of search are thus displayed at the correct range and bearing. There is of course a distortion in this kind of display, and from some points of view a triangular display, which would more nearly resemble a P.P.I. sector, should be preferable. Experience, however, shows that this is not satisfactory owing to the crowding of echoes at short ranges.

The width of the transmitted and receiving beam in the plane perpendicular to that of the sector of search

may be as large or small as is desired or necessitated by particular applications. In typical experimental equipments this beamwidth has been 12°, but it is now thought that for many applications a width of perhaps 5° would be better.

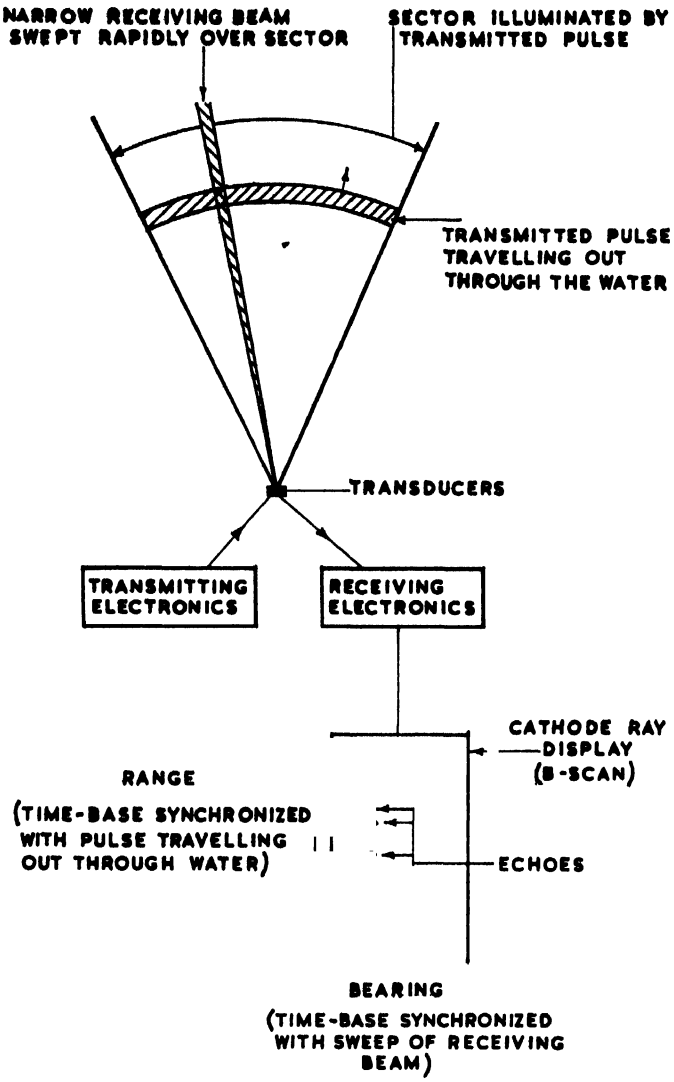

Fig. 1. Schematic diagram of sector-scanning sonar.

In order to scan a sector with a receiving beam which is one *n*th the width of the sector, it is necessary to have the receiving transducer divided into *n* sections and to have *n* electronic channels connecting these sections to the later parts of the receiving electronic system. The expense of the system is therefore to some extent increased by having a larger number of beamwidths within the sector, in other words by increasing the resolution of the system. The order of resolution which it is thought would be readily feasible and commercially worthwhile is perhaps 1° angular resolution[1] and one m range resolution in a system operating around 50 to 100 kc/s and giving ranges between 500 and 1,000 m on fish schools. Very much higher resolution is worthwhile in applications where shorter ranges are acceptable, and a recent equipment has given a resolution of half a degree in angle and about 10 cm in range up to a maximum range of about 100 m. The former system would be suitable for detecting large fish such as cod, or small schools of fish, at reasonable distances. The latter system is intended for the observation of fish movements and perhaps the identification of individual fish in more limited situations, notably in enclosed waters, and in positions of special significance such as the intake to the turbines of hydro-electric power stations and to the cooling water system of thermal power stations, the observations of fish entering nets, and so on.

Observation of fish in midwater

One of the difficulties in sonar work when using beams which are very nearly horizontal is that the scattering of sound from the sea bottom (also from the sea surface) produces a background against which it may be difficult to detect fish. If the water is fairly deep, it is possible to have the beam clear of both the surface and the bottom up to quite reasonable ranges, and in these circumstances midwater fish may be detected without difficulty. The parameters of the system are then not very critical, and success has been obtained with ordinary single-beam sonars having beamwidths of as much as 5°. Of course the problem of search still remains, but perhaps with 5° beams the time required to search a sector is not prohibitive. Nevertheless a simple electronic-scanning system can give a very considerable advantage, and with a resolution of 5°, not many channels are needed to cover a big sector. Thus the equipment need not be very expensive. But obviously if a narrower beam is used, say 1° in plan (although it may be say 10° vertically), much better resolution is obtained and the details of the fish school are more clearly determined.

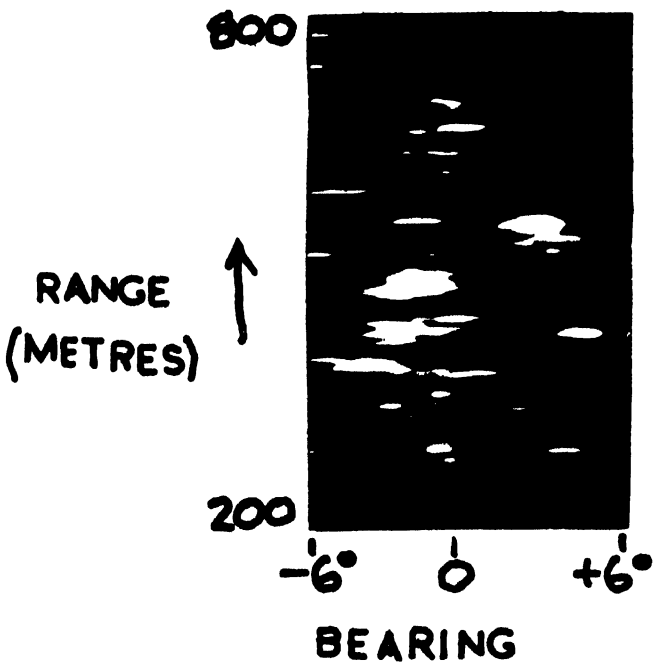

Fig. 2. Typical 8-channel sector-scanning display showing small fish schools. (Horizontal beam.)

Echo sounders, i.e. sonars with their beam axes vertical, are frequently used for detecting midwater fish. They are very successful in this role in spite of having very wide beams, often over 30°, because there is no possibility of bottom or surface reverberation forming a background at the same range as the fish. The only background is volume reverberation, i.e. scattering from particles and bubbles, etc. in the water, and this reverberation is generally of very low level. But even with such a system as this, although detection is very good, resolution is poor and the details of schools cannot be determined. So here again the use of electronic sector scanning could be an asset, and only a relatively small number of channels would be required to give a very big improvement in the information obtained.

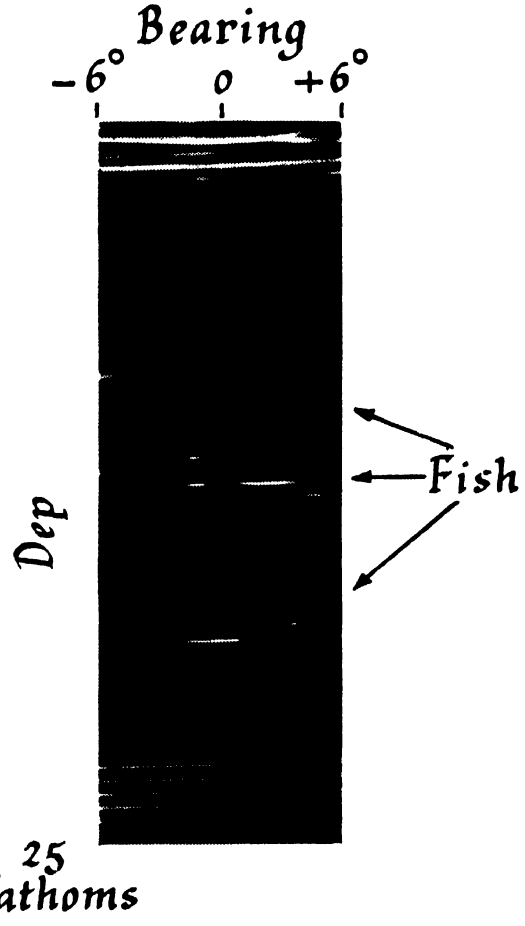

Fig. 3. Typical 8-channel display with sector axis vertically below ship.

Some examples of results obtained in a relatively simple eight-channel electronic sector scanning sonar are shown in Figs. 2 and 3. In this system the acoustic frequency was 37 kc/s, the horizontal beamwidth was 1·5°, the pulse duration was 1·0 millisec, and the vertical beamwidth was 12°. Since there were eight channels, the width of the scanned sector was about 12°. Fig. 2 shows some results obtained with an almost horizontal beam, scanning in the horizontal direction. In interpreting this display it must of course be realised that the range and bearing scales are such that a true plan view is not presented. But it can clearly be seen how the small schools of fish are distributed and it is not difficult to interpret these in strict geometric terms if required. Since all this information is obtained on one single transmitted pulse, it is clear that there is no confusion due to movement of the fish or of the boat while the search is being made.

Fig. 3 shows a result obtained with the axis of the scanned sector vertically below the ship. The parameters of the system were the same as in Fig. 2 but, owing to the short range at which the fish are now being detected (the depth of the water was only about 40 m), it is likely that at least some of the echoes shown are due to individual fish (probably herring).

It will be seen that, even with such a comparatively crude system, the improvement in the information obtained over that obtained with an ordinary sonar is very marked.

Detection of fish very close to the sea bottom

An important problem in fisheries is the detection of fish near the sea bottom because this is where a very great deal of trawling has to be done. If the beam is directed at a shallow angle to the bottom, it is clear that fish near the bottom have to be detected against a background of the reverberation, or backscattering from the bottom itself. Because of this factor most commercial single-beam sonars have not been very successful in this role. With a beamwidth as wide as 5° horizontally, too much of the bottom is taken in by the pulse and the reverberation from this is ample to drown the echoes from fish.

The use of an electronic sector-scanning sonar using horizontal scanning, as in the example shown in Fig. 2, can effect a very considerable improvement because it permits the use of very much narrower beams, thus greatly improving the ratio of fish echo to reverberation background. The typical result shown in Fig. 2, indeed, was taken under conditions where bottom reverberation was of importance because the depth of water was only about 40 m and, with the vertical beamwidth of 12°, bottom reverberation was, in fact, being received over most of the range. It will nevertheless be seen that the fish schools show up quite clearly in spite of this. There is no doubt, however, that bottom reverberation must be always a limiting factor in the detection of fish when the sonar system is used in this way.

Recently a completely novel way of utilising a sector-scanning sonar for the detection of fish very near the bottom has been proposed by Dr. F. R. Harden Jones of the Lowestoft Fisheries Laboratory. The principle of this new system is shown diagrammatically in Fig. 4. Instead of the beam scanning horizontally, it now scans vertically as indicated by the arrows in the diagram. The beamwidth in the direction at right angles to the plane of the diagram may be quite considerable, and something between 5° and 12° is thought to be most suitable. As the receiving beam (narrow in the vertical plane) swings up and down as indicated, it returns echoes from the sea bottom varying from comparatively short range in the lowest position to a comparatively long range in the highest position; the sea bottom returns,

therefore, appear as a curved line on the B-scan display as shown in Fig. 5. Any fish near the bottom, such as those indicated by numbered dots in Fig. 4, return echoes which are received before the bottom echo for the particular beam position along which they are received. The fish echoes therefore appear clear of the sea bottom echo, as shown by the numbered echoes in Fig. 5. This, therefore, is a very effective system of obtaining echoes from fish very near the bottom without interference from the bottom returns themselves. In fact the bottom returns are made use of to provide a reference line on the display. In a way this new system is a compromise between the ordinary conception of scanning ahead of the ship and the conception of the echo sounder.

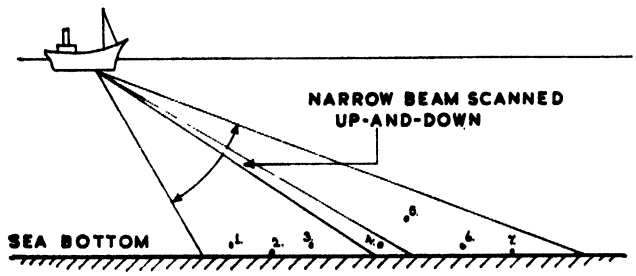

Fig. 4. Application of sector-scanning sonar for the detection of fish near the sea bottom.

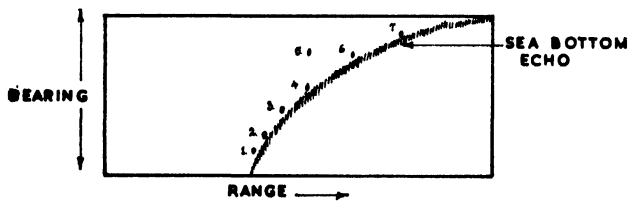

Fig. 5. Display obtained by method of Fig. 4.

But scanning in this particular way clearly gives some very considerable advantages.

Although no experiments have yet been carried out at sea using this method of search, some very extensive trials of it have been made in a large seawater tank at Cairn Ryan. The experimental electronic sector-scanning sonar used for these trials was a high-resolution equipment having 30 channels, so that 30 beamwidths are scanned within the sector. Moreover, the system was provided with a special kind of signal processing which enables double the angular resolution of a normal acoustic system to be obtained with the same size of transducer. In this experimental equipment the acoustic frequency was 500 kc/s, and the pulse duration was 0·1 millisec, giving a resolution of about 10 cm in range. The sector width was 30°, and the resolution was about 0·5°. The sea bottom was simulated by the concrete wall of the tank or by a corrugated sheet, and fish targets close to the bottom were simulated by artificial small targets or by actual fish suspended in position near the wall. Some typical displays obtained in this trial are shown in Fig. 6. It will be seen that they reproduce the theoretically expected picture exactly, and promise great success for Dr. Jones's system. It is intended to carry out operational sea trials of this method next winter, using an acoustic frequency of 100 kc/s, with an angular resolution of 1°. It seems probable that success will be obtained, and that this will prove a most important development in the use of sonar in fisheries.

[1] By "angular resolution" is meant the smallest angular step over which a change in target strength can be detected. The problem of separate detection of two fish with a clear patch between them, or of one fish clear of the bottom, involves *two* such steps. Thus

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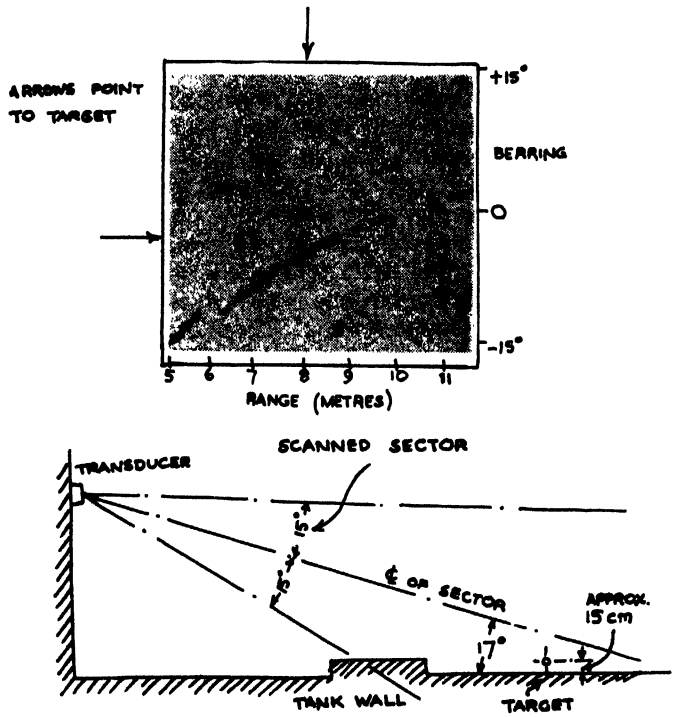

Fig. 6. (a) Typical results with 30-channel system.

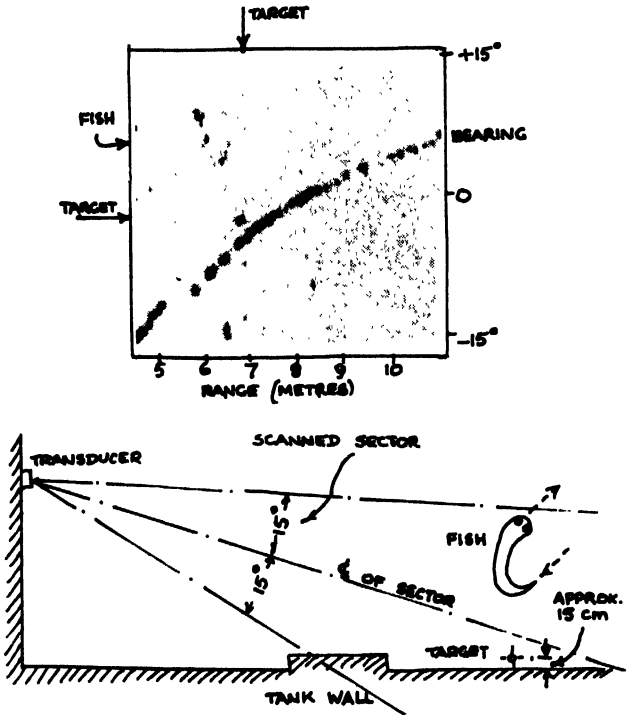

Fig. 6. (b) Typical results with 30-channel system.

A New Sonar System for Marine Research Purposes

Abstract

A complete "search installation" comprises two combined sounder/sonar sets working on 11 kc/s and 30 kc/s and two additional sounders on 38 kc/s and 18 kc/s. The remote controlled sonar transducers are housed in a retractable 18 knots dome. The transmitters have variable pulselength and an output power of 8·5 kw. The receiving equipment is calibrated and comprises special circuits for TVG, RCG and White Line features. Display and recording equipment includes range/depth recorders, tape recorder, loudspeaker and an oscilloscope for detailed echo studies and play back of tape recordings. The whole installation, including two additional sounders, is manned by a single operator.

Un nouveau systeme sonar pour la recherche maritime

Résumé

Cette "installation de Recherche" complète comprend 2 sondeurs/sonar fonctionnant à 11 kc/s et 30 kc/s et 2 sondeurs supplémentaires, fonctionnant sur 38 kc/s et 18 kc/s. Les émetteurs de sonar sont enfermés sous un dome escamotable, capable de résister à une vitesse du bateau de 18 noeuds. Les émetteurs ont des pulsations de longueur variable et leur puissance d'émission est de 8,5 kw. L'équipement de réception est calibré et comprend des circuits spéciaux pour TVG, RCG et des caractéristiques de "ligne blanche". L'équipement d'étalage visuel et d'enregistrement comprend enregistreur de portée/profondeur, enregistreur sur bande, haut-parleur et un oscilloscope pour les études détaillées des échos et le renvoi des enregistrements à bande. Toute l'installation, y compris les deux sondeurs supplémentaires, est manipulée par un seul opérateur.

Nuevo sistema de sonar para investigaciones marinas

Extracto

Una "instalación de búsqueda" completa consta de dos grupos combinados de sonda y sonar que functionan a 11 kc y 30 kc/seg y 2 sondadores adicionales a 38 kc y 18 kc/seg. Los transductores del sonar con sus telemandos están montados en una cúpula retractable capaz de resistir velocidades hasta de 18 nudos y las presiones que las acompañan. La longitud de los impulsos de los transmisores son variables y la potencia es de 8,5 kv. El equipo receptor está calibrado y comprende circuitos especiales para "TVG", "RCG" y línea blanca. El material de presentación visual y de registro comprende registradores del alcance y la profundidad, un registrador de cinta, un altavoz y un osciloscopio para estudiar los ecos con detalle y repetir los registros de las cintas. De toda la instalación, incluídos dos sondadores adicionales, se encarga un solo operador.

by

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MARINE biologists were the first to prove that sonar had a practical use in locating schools of fish. Naval sonar sets were first used but were in many ways quite unsuitable. In spite of this lack of satisfactory equipment, sonar soon became an indispensable tool in needed marine research. During the last decade sonar has been installed in many research vessels, but until recently scientists have been forced to use either relatively simple equipment designed for fishing, or modified and even obsolete naval equipment.

This paper gives a short description of a new sonar system specially designed for research purposes.

By 1959 a great deal of experience was available about the use of sonar for locating fish. One research vessel alone had used sonar for over 30,000 hrs and a large number of active fishermen had also been using sonar for several years.

Purpose

The purpose of the new system can thus be outlined:

(a) Ocean-wide and coastal search for fishable concentrations in direct support to the fishing fleet.

(b) Perfection of the sonar and sounder search programmes and doctrines, to improve own methods and procedures and as a part of a training programme for fishermen.

(c) Behaviour studies and study of the level and frequency dependence of the "target strength" of various sizes of fish.

Other aims and tasks are for example the study of dispersion, the correlation of recording to catch and the counting of single fish.

After close study the main technical specifications were formulated:

(a) The installation should comprise two separate

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when the angular resolution is stated to be 1°, this means that a fish can be observed as a separate entity, provided its angular separation from another fish or from the bottom is at least 2°. The interpretation of range resolution is similar.

Acknowledgements

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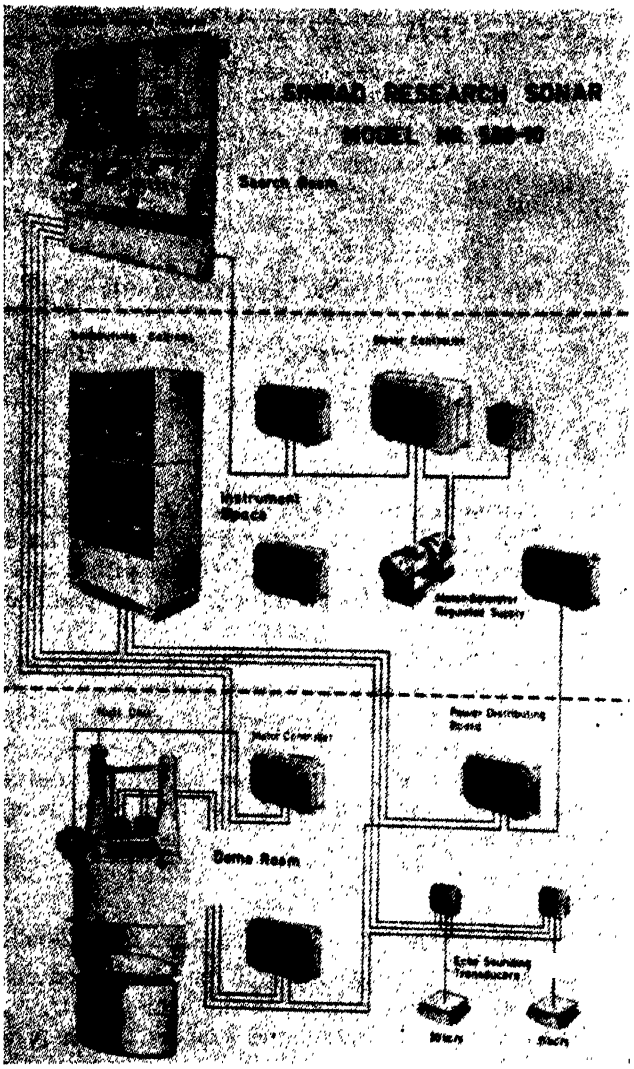

Fig 1. System pictorial diagram of SIMRAD research sonar model No. 580-10.

single beam searchlight sonar systems with both of the sonar transducers in the same dome.

(b) The transducers and transmitters should be designed to give the highest possible "source level" (of the order of 125 db and 115 db//1μ Bar, ref 1 m for 30 kc/s and 11 kc/s respectively), within the limited space available for the dome and the hull unit.

(c) The display should comprise range-depth recorder, oscilloscope. tape recorder, loudspeaker and headphones.

(d) The entire installation should be calibrated to facilitate routine measurement of echo level. The receiver in particular must have the correct characteristics (dynamic range, RCG, TVG and "white line" feature) and a good long-time stability.

(e) The Operator's Display Console should be designed in such a way that the whole installation plus two separate echo sounders can be supervised by one operator.

(f) The installation should, as far as possible, be composed of self-contained units which can be inspected and tested during operation.

(g) All units of the system should be designed for continuous service (the estimated number of working hours per annum will be approximately 3,000).

The system described

The system comprises three main units (Fig. 1): hull unit, transmitting cabinet and operator's display console.

A complete installation also includes transducers for echo sounding, a stabilised converter and a number of junction and distribution boxes. The mechanical construction of the chassis, cabinets and similar items is mainly conventional.

Hull unit—The hull unit (Fig. 2) has two lifting columns by which a streamlined dome can be lowered into its working position underneath the ship and retracted into an inboard trunk when the system is not in use.

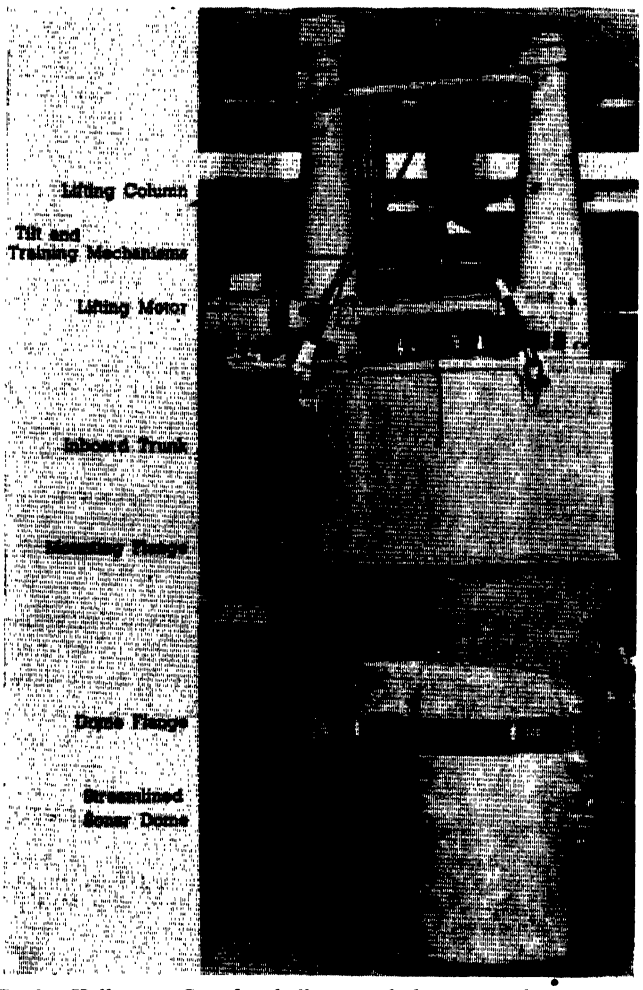

Fig 2. Hull unit. Complete hull unit with dome in working position (lowered) assembled at the factory for final tests. Total height from underside dome to top of lifting column: 3,950 mm (158 in). Length: 1,750 mm (70 in). Width 840 mm (33 in). Depth below the keel with dome in working position: 1,100 mm (44 in). Total weight: 1,300 kg (2,800 lb).

The lifting columns and trunk are maintained from earlier naval equipment. The dome is 60 in long, 24 in wide and 52 in high. It is constructed entirely of stainless steel and designed for 18 knots operational speed. The dome houses two transducers which are mounted so that they do not interfere with each other. The rear transducer (11 kc/s) is the lower and is trainable only, while the forward transducer (30 kc/s) is both trainable and tiltable down to 90°. The training and tilt mechanisms with the servomotors, gear, synchros and sliprings (Fig. 4) are mounted at the upper end of the transducer shafts, which go through packing glands in the top of the trunk. When the dome is raised the transducers can be removed without docking the ship.

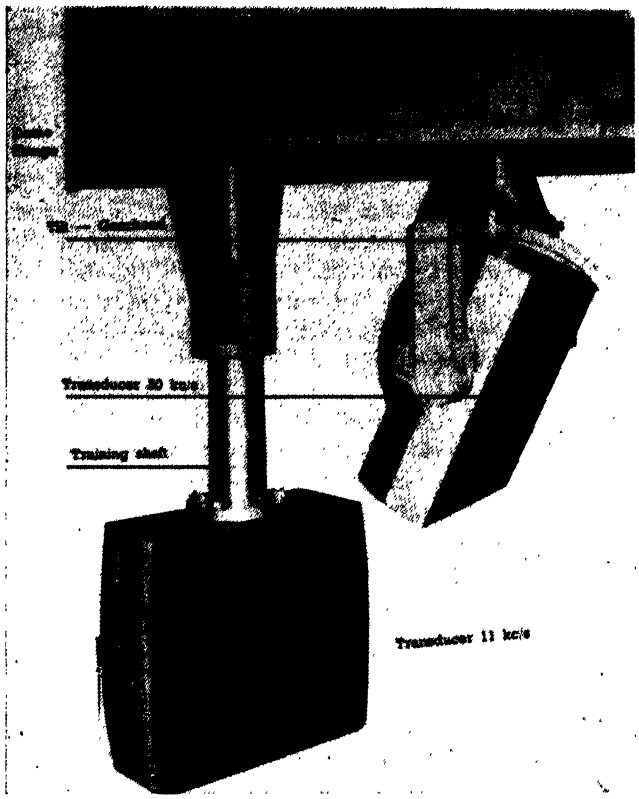

Fig 3. Sonar transducers. Close-up view of sonar transducers (dome removed). The 30 kc/sec transducer is tiltable and trainable. The 11 kc/sec transducer is trainable only. With the dome in the hoisted position, the transducers may be removed while the ship is afloat.

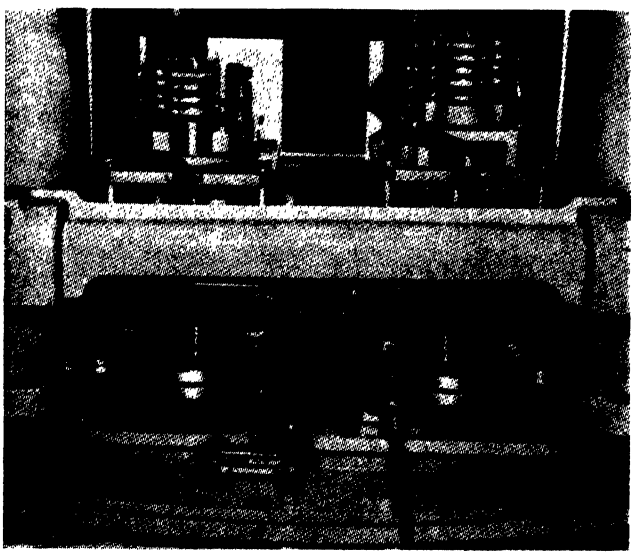

Fig 4. Tilt and training mechanisms. Close-up view of tilt and training mechanisms with covers removed. The positioning of the transducers to any desired bearing is by servo systems controlled from the operator's display console.

Transmitting cabinet—This unit (Fig. 5) contains two complete transmitters and all the servo-amplifiers. Each of the two identical transmitters occupies 2½ drawers in the cabinet and the sixth drawer houses five servo-amplifiers with the test unit and power pack. All

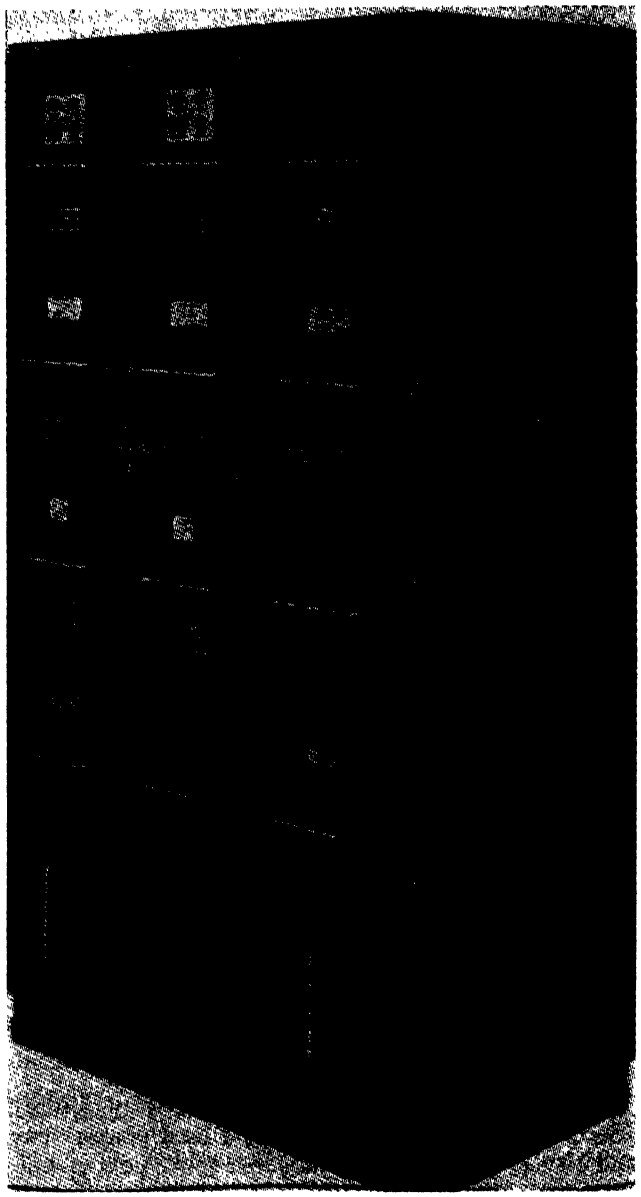

Fig 5. Transmitting cabinet. This cabinet contains two complete high power transmitters (30 kc/s and 11 kc/s) and the servo-amplifiers. The components are mounted on six drawers running on telescopic mountings allowing easy withdrawal for service and maintenance. The outside dimensions are: height, 1,860 mm (73 in), width, 1,050 mm (44 in), depth, 655 mm (26 in). The total weight is 800 kg (1,700 lb).

the drawers glide on telescopic runners and are fitted with door switches and door stops. The output stage of the transmitter consists of four 7094 valves in a push-pull parallel coupling. With an anode voltage of 3,000 V and a reservoir condenser of 150 μF, 3,000 V, the transmitter gives a pulse effect of approximately 8·5 kw, measured at the beginning of the pulse and a pulse energy of 300 w sec with a pulse-length of 80 ms. The transmitter and the servo-amplifier are controlled from the operator's display console.

Operator's display console—To meet the demand that the system (Fig. 6) can be operated by *one* man, all the control and display instruments are arranged in a piano-like cabinet. Definite maximum measurements for the cabinet's height and depth were laid down. The width of the cabinet was decided by the fact that the operator had to be able to reach all the knobs and switches and, at the same time, see and operate two separate echo sounders, which were to be mounted outside the cabinet, one on each side.

Fig 6. Operator's display console. All receiving and display units for both sets are arranged in this console in a manner to facilitate the supervision by one operator. The top section contains the receivers, master keying circuits, tape recorder and main starting board. The graphical recorders, selection panes, bearing indicator and CRT display are all arranged on the sloping front of the console. Two additional echo sounders are to be mounted outside the console in a position where they can be watched by the operator.

In constructing the operator's display console, effort was made to place the most-used control panel and display instruments in the most convenient position, i.e. as near the centre of the console as possible.

The console is constructed with a middle section which contains, at the top, the start panel for the whole system, with voltmeters, frequency meter, clock and elapsed time meter. A commercial tape recorder is mounted underneath these instruments and, in the sloping front, right in front of the operator, are the tilt and bearing indicators and the oscilloscope. All these units are common for both the sonar sets.

The two sections, one on each side of the middle panel, are identical. The receiver is mounted in the vertical part and the selection panel and recorder in the sloping front. All these units are mounted on telescopic runners and can be pulled out while the system is in use. The terminal strips for the entire system are in the base of the console.

In commercial equipment of a similar type which is to be operated by unskilled or semi-skilled personnel, it is common practice to restrict the number of controls as much as possible. In this special system for scientific use, the exact opposite has been decided upon and a number of the parameters in the system are kept variable so that an experienced operator has an opportunity of choosing "optimum" characteristics under different conditions. As a result, each of the two sonar systems has 40 control switches.

Important control functions

A detailed technical description of all units is outside the scope of this paper and only the more important control functions are therefore mentioned:

The polar diagram of the transducers can be varied in one plane with the switches on the selection panels.

The output effect of the transmitter can be regulated in three stages and the pulselength in six stages.

The training programme is either manual or automatic with a variable stepping angle. The transducer's movements are governed by a conventional servo-system which uses two inch synchros, split-field motors and transistorised amplifiers.

The receiver has variable band width, a specially large dynamic range, "time variable gain" with a selectable function, automatic gain control, special circuits for white line effect and calibrated gain control.

The range-depth recorder has four basic ranges, 16 phasing ranges in all, variable paper speed and a high pulse rate.

The oscilloscope is designed for three different purposes:

(i) A PPI indicator for sonar.
(ii) A calibrated nonius for measuring the echo level.
(iii) A bottom lock in connection with the tape recorder.

The oscilloscope is supplied with a built-in delay line which makes it possible for the sweep to be triggered by the echo. The oscilloscope has a 7 in CRT and P7 screen.

A somewhat modified commercial stereo tape recorder has been used in which one of the channels can be used for simultaneous commentary. During recording the tape can be supplied with sweep trigger pulses for later play-backs and display on the oscilloscope. Recording on the tape recorder can take place simultaneously with, and independently of, the registration on the range-depth recorder and display on the oscilloscope.

The operator's display console is connected to the ship's intercommunication system, so that in certain situations the operator can give orders straight to the helmsman.

In addition to the three main units, a complete installation also includes junction and distribution boxes and a frequency stabilised converter which supplied 220 V, 50 c/s ±0·1 per cent. This converter is only used for the recorder motors. The ship's 220 V, 50 c/s network supplies the power for all the other units.

The echo sounders

Both of the two sonar systems (11 and 30 kc/s) of which the installation consists, can also be used as echo sounders. When used for scientific work, an additional two echo sounders are necessary for some investigations. These special sounders work on 18 and 38 kc/s, and both are equipped with variable polar diagrams, several depth scales and special white line properties. The echo sounders are placed so that they are easily observed from the operator's seat.

In addition a 50 kc/s echo sounder is mounted on the bridge for navigational purposes.

Operational use of the system

A detailed procedure for the operational use of the system will not be laid down until some of the special features have been more fully explored. The following notes are merely an indication of the utilisation of the system under various modes of operation.

Sonar search—The aim is to find as many schools of fish as possible, either as a phase in a scientific investigation, or in direct support to the fishermen. As the greatest possible detection range in this case is of interest, both the systems are used on full power concurrently, with a long pulse, a narrow bandwidth and an automatic search programme which gives a comprehensive coverage. The operator can listen to one or both of the systems and record on the tape recorder any items he thinks might be of special interest. These tape recordings can be studied in detail later. The echo traces from the range recorders are also preserved for later examination.

Sonar close contact—A range of less than 500 m is called close contact. Under certain conditions it is of interest, for example in connection with experimental fishing and during study of fish migration, to keep contact with one particular school. The operator then directs (tilt and training) the 30 kc/s system and gets a PPI picture of the school on the oscilloscope. During this operation (particularly in shallow water) reduced pulse effect and short pulse may give increased resolution.

On the oscilloscope it is possible to compare the form of the transmitted pulse with the returned echo in the hope of finding a correlation between the pulse deformation and the species and configuration of the fish in the school.

While the operator thus diverts most of his attention to the study of one particular school, the low frequency set can be kept running on an automatic long range search programme, i.e. on the look out for other schools.

General echo-sounding survey—Since many types of fish appear both pelagic and close to the sea bottom, it is necessary in a comprehensive survey to cover the whole depth range with high resolution recordings.

The usual procedure is to use one system as an echo sounder on a survey range of, for example, 500 m. The other system and the two additional sounders can then cover different "phasing ranges" of the total depth range and record the echoes with high resolution. With the wide choice of frequencies and polar diagrams at one's disposal, it will always be possible to get a good coverage.

The tape recorder can also be used during echo-sounding surveys and it has already proved to be of special value to compare the echo recordings on the paper with echo signals on the tape recorder when they are later displayed on the oscilloscope and studied at leisure. This procedure is of great interest since otherwise valuable information would be lost due to lengthy and intense observation of the oscilloscope being extremely tiring.

Measurement of the echo level—Both systems are calibrated so that quantitative measurements of the echo strength from single fish can be obtained. This means that the "source level" during transmission and the total amplification of the receiving equipment is known. The gain controls on both receiver and oscilloscope are calibrated in db and by noting a certain reading on the oscilloscope one can, by simple addition and subtraction, read the echo level in db's referred to 1μ Bar.

The main difficulty, of course, is that the fish is not stationary and, as a rule, one knows neither the size nor species of the fish which gives the echo. Preliminary experiments with live fish hooked on to a short line fixed to a vertical wire have, however, given promising results.

It is expected that proposed investigations with an underwater camera and TV will give even more valuable data. The aim is partly to be able to judge the size of the fish from measurement of the echo level.

Fish counting—In certain investigations, the task is to estimate the amount of fish in a given area. It has already become apparent that the high "source level" and good resolution of these systems has considerably eased this problem even though the manual counting of the recorded echoes is still extremely tedious. With the high signal-to-noise ratio obtained on echoes from single fish, even at the greatest trawl depths, it might be a practical proposition to supplement the installation with an automatic fish counter.

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Detection et Localisation des Bancs de Poissons

L'étude passe en revue quelques signes de nature biologique, océanographique et saisonnière sur lesquels, depuis des siècles, les pêcheurs se sont basés pour prédire et détecter la présence de bancs de poissons. L'application de méthodes modernes de détection et localisation a transformé ces prédictions (qui étaient toutes basées sur des déductions d'informations secondaires) en détection réelle basée sur des échos venant des bancs ou par l'observation directe des poissons eux-mêmes. Il est montré que les méthodes telles que l'enregistreur japonais de sons de poissons "Sonobuoy" et la "prospection aérienne" sont très peu employées pour des raisons diverses. Quant au "thermo-indicateur" utilisé dans la pêche du thon, il ne peut être considéré comme détecteur de poisson, bien qu'il soit à la base de la pêche à la longue ligne du thon; il donne des indications sur les conditions océanographiques plutôt que sur les poissons eux-mêmes. Les techniques actuelles d'écho-sondage se sont beaucoup développées depuis le premier Congrès Mondial des Engins de Pêche en 1957, alors que la détection était encore le problème principal. Aujourd'hui les instruments électroniques ont tellement évolué que la détection est admise par tous et que les études sont maintenant dirigées vers la reconnaissance des espèces de poissons par l'interprétation des traces obtenues sur les échogrammes. Les traces caractéristiques des différents poissons sont aujourd'hui reconnaissables grâce aux ingénieurs qui ont quitté leurs laboratoires et font désormais leurs essais en mer, à bord de bateaux de recherche, équipés dans ce but. Il est regrettable que beaucoup de pêcheurs utilisent encore leur écho-sondeur pour mesurer la profondeur des fonds et non pour détecter les poissons; il est nécessaire que des cours soient organisés dans les écoles de pêche pour leur apprendre à interpréter les traces d'échos. La communication est illustrée de 10 échogrammes typiques de différentes espèces de poissons, avec commentaires sur les caractères individuels des traces.

The detection and location of fish schools

Abstract

The paper reviews some of the traditional biological, oceanographical and seasonal signs which fishermen have always depended on to predict and detect the presence of fish schools. The application of modern detection and location methods has changed such predictions (which are all based on the deduction from ancillary information) to real detection based on echoes from, or direct observation of, the fish themselves. It is pointed out that methods such as the Japanese "Sonobuoy" fish noise recorder and aerial spotting are either very restricted in their application or very expensive and therefore only usable under specific conditions. The various thermo-indicators, as used for instance in tuna fishing, can hardly be classed as fish detection devices, although they are perhaps at the base of the tuna longline fishing. They provide indications of oceanographical conditions rather than of the fish themselves. The present echo-sounding technique has developed fast since the time of the First Fishing Gear Congress in 1957, when detection itself was still the main problem. Today electronic devices have been so much developed that detection itself is taken for granted and studies are now directed more towards recognising individual fish from the traces obtained on the echograms. The characteristic traces of many fish species are now recognisable, largely due to the fact that the engineers have left their laboratories and are now making their tests at sea on board vessels equipped for this purpose. As many fishermen still use their echo sounder as a depth recorder rather than a fish finder, it seems highly necessary that courses on the recognition of echogram traces should be given in fishery schools. The paper, which includes ten typical echograms of different fish species, discusses each of these and points to the characteristic individual difference of the traces.

Deteccion y localizacion de cardumenes

Extracto

Reseña el autor algunas de las señales biológicas, oceanográficas y estacionales de las que los pescadores se sirven desde tiempo inmemorial para predecir y localizar la presencia de cardúmenes. La aplicación de los métodos modernos ha transformado tales predicciones (basadas todas en deducciones de datos auxiliares) en una verdadera localización fundamentada en los ecos de los peces o en la observación directa de éstos. Se pone de relieve que métodos como el registrador japonés de sonidos emitidos por los peces "Sonobuoy" y la localización aérea son de aplicación muy restringida o muy costosos y, por tanto, factibles de usarlos solamente en condiciones especiales. Los diversos termoindicadores, como los empleados, por ejemplo, en la pesca del atún, apenas pueden clasificarse como dispositivos de localización de peces, aunque probablemente constituyen la base de la pesca del atún con palangres, porque dan información de condiciones oceanográficas más bien que de los peces. La actual técnica de ecosondaje ha evolucionado rápidamente desde el Primer Congreso de Artes de Pesca de 1957, fecha en la que la localización misma era todavía el problema principal. Actualmente los dispositivos electrónicos han mejorado de tal manera que la localización se acepta como normal y los estudios se dirigen hacia el reconocimiento de peces individuales a partir de los trazos obtenidos en los ecogramas. Se reconocen los trazos característicos de muchas especies de peces debido principalmente a que los ingenieros han salido de los laboratorios y realizan los ensayos a bordo de embarcaciones equipadas para ello. Como muchos pescadores siguen empleando sus ecosondas para registrar la profundidad más bien que para localizar peces, parece ser muy necesario que en las escuelas de pesca se den cursos sobre el reconocimiento de los trazod en los ecogramas. Esta comunicación, que da 10 ecogramas típicos de diferentes especies de peces, discute cada una e indica las diferencias individuales características de los trazos.

by

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Commission Marine Marchande et Pêche

DEPUIS que la pêche existe, les hommes ont toujours essayé de localiser les points possibles où ils avaient le plus de chance de jeter leurs lignes, leurs pièges ou leurs filets.

L'observation de la mer, du temps, et des oiseaux étaient restés la base de leurs déductions jusqu'à l'apparition récente des ultra-sons.

Les Basques, par exemple, estimaient que pour la capture du thon dans le Golfe de Gascogne, le temps devait être beau, la mer calme, avec risées de vent d'Ouest, Sud-Ouest, Nord-Ouest. Les vents contraires étaient ceux venant de terre soit Nord-Est et Sud-Est.

Ils ont utilisé pendant longtemps des méthodes visuelles de localisation des thons. Par mer faiblement agitée, les Basques savent reconnaître ce qu'ils qualifient de "legouna", qui est un freinage de la houle de vent par la masse de poissons progressant dans le même sens que la houle.

Si la houle est forte, ils savent distinguer dans l'épaisseur de la vague, sous une forme d'ombre couleur chocolat la présence de thons. Cette observation porte le nom de "gorrian-gory" (rouge dans le rouge).

Pour les Basques, le comportement de certains oiseaux est une indication de la présence de bancs de poissons (Fous de Bassan, Sternes et Laridés).

Mais pour le thon, ils s'en rapportent à certains puffins, particulièrement le "Martina" et le "Carcoulos" qui est un macareux. Ils se trompent rarement, le "Martina" est incapable de plonger, mais son vol rapide lui permet de vivre des petits poissons (anchois) que les thons chassent vers la surface en les poursuivant.

Si au cours de la nuits les bancs de germon se sont déplacés de 15 à 20 milles, les Basques les retrouvent, grâce à l'observation d'un ratissage de la mer opéré par les "Martina" volant en explorateurs, en ligne parallèle, qui tournent alors en groupe aussitôt qu'ils soupçonnent la présence d'un banc de thons. Ce vol tournant, dénommé "Chobaya" signale de loin aux pêcheurs que les thons viennent de monter en surface.

Les pêcheurs espagnols et portugais de la côte atlantique, utilisent les mêmes méthodes basées sur l'observation des oiseaux de mer.

La pêche devait commencer suivant la précocité du printemps, c'est-à-dire, suivant le réchauffement des eaux et seulement aux points de rencontres de courants contraires.

Cette théorie s'est vérifiée expérimentalement lors des campagnes océanographiques effectuées par les bâtiments de recherches. Il a été remarqué en effet que le germon apparaissait dans les zones de contraste entre des eaux d'origines différentes.

Les zones de premières captures se situent l'une dans le Nord-Est des Açores et l'autre au large des côtes espagnoles et portugaises (60 à 100 milles du littoral). Entre ces deux zones, malgré une température d'eau favorable, on ne trouve pratiquement pas de thons. La distribution des eaux y est régulière, alors qu'elle est perturbée dans les zones fécondes par des eaux entre 15 et 16° remontant vers le Nord et qui se heurtent à un contre courant plus frais qui descend du Cap Finistère aux Berlingues. Dans le Golfe de Gascogne c'est aux points de rencontre d'eaux de températures différentes que se pêche le germon.

Cette théorie de la rencontre d'eaux différentes dans toutes les mers justifie la présence de beaucoup de migrateurs et de poissons voyageurs, notamment les morues en Islande et Terre Neuve, et dans le Pacifique le grouillement de faune aux points de rencontre des grands courants équatoriaux. C'est incontestablement la fusion d'eaux différentes qui modifie le caractère des facteurs physico-chimiques qui conditionne la répartition, la nature et l'abondance du plancton.

En méditerranée on considère favorables pour la pêche du gros thon rouge par les madragues: une eau bleue, une transparence de l'eau permettant de voir le disque de Secchi à 17/18 mètres, un vent d'Est assez fort.

Pour les bonites (*Sarda sarda*) les pêcheurs recherchent une eau bleue, les vols et plongeons d'oiseaux de mer (Petrels, sternes) qui signalent les bancs d'anchois ou de sardinelles susceptibles d'attirer les prédateurs. La présence et la direction des bancs de dauphins sont une indication, pour la même raison.

Au Maroc, on situe la sardine en eau verte, le dégagement de bulles d'air provoqué parfois par les grosses sardines nageant en profondeur est une indication, ainsi que le vol des oiseaux et leurs plongées.

Il serait fastidieux de traiter ici de tous les procédés empiriques de la localisation des espèces dans le monde, d'ailleurs influencés par les phases de la lune qui restent un élément dominant pour les pêches littorales.

Nous devons cependant mentionner pour mémoire "la prospection aérienne" au nombre des moyens modernes propres à faciliter la localisation des bancs de thons. C'est une histoire enterrée, bien qu'elle trouve encore de temps en temps un certain regain d'actualité. Les Américains l'utilisent en Californie avec des avions spéciaux pour rechercher la sardine. Cette prospection, pour être valable, exige des moyens financiers puissants. Elle ne nous paraît possible que dans certaines mers, dans des régions calmes, et à condition d'être appliquée sur un plan communautaire de flottilles.

Il existe également une méthode de repérage du poisson par "Sonobuoy", procédé japonais basé sur le bruit produit par le déplacement sous l'eau des bancs.

Le dispositif utilise la modulation de fréquence à la très haute fréquence de 42 mégacycles. Mais il semble avoir seulement été utilisé pour déterminer les quantités de poissons heurtant ou se maillant dans des filets côtiers. Il transmet des indications graphiques à environ 10 kilomètres. Ce dispositif est inconnu en Europe et nous ne le citons que pour mémoire.

Enfin nous devons mentionner que la méthode du "Thermo-Enregistreur", bien que ne remplaçant nullement le sondage par écho pour le repérage du poisson, peut tout de même être considérée comme un auxiliaire pour le pêcheur de thon. Cet instrument qui enregistre d'une manière continue tout changement de température associé à une remontée d'eau, variation de couleur, peut être interpreté comme propice à la présence de thons. Les points où se produisent de brusques changements de température des eaux de surfaces, ainsi qu'un changement de couleur d'eau sont propices à cette présence. Le thon à une répugnance marquée à passer de l'eau chaude (14°5) à une eau moins chaude. C'est ce qui, vraisemblablement, amène les thons éparpillés à former des bancs dans un même milieu isotherme dans lequel ils évoluent. Il devient grégaire et suit, à travers les modifications de température des eaux de surfaces, la zone où il se plait.

Sondeur A echo

Le sondeur à écho est à l'origine d'une véritable révolution dans la recherche et la localisation des espèces.

La Technique électronique, en constante évolution, autorise aujourd'hui tous les espoirs. L'identification des espèces pélagiques à nage rapide et à grande migration, comme le thon, est entrée dans la pratique courante des pêches, alors qu'à l'époque du précédent Congrès de Hambourg, on la considérait comme une performance,

et que la majorité des pêcheurs la jugeait même impossible.

Sur le plan technique de la recherche et des améliorations à apporter au sondeur, un élément capital de succès, réside dans le fait, que les Ingénieurs, qui se contentaient d'exécuter des mesures en laboratoire, à l'aide d'une cuve d'eau à échos à plan réflecteur mobile, ont substitué à cette méthode les essais réels à bord d'un navire en mer équipé pour cette fin.

Il faut regretter qu'une importante partie des pêcheurs font encore fonctionner leurs échomètres en sondeurs de fond, et non en détecteurs de poissons.

Il apparaît actuellement indispensable, que dans les Ecoles de Pêche, l'enseignement comporte des exercices réels de localisation du poisson par les ultra-sons, et que cet enseignement pour être valable, ne peut avoir lieu qu'à bord d'un navire.

Morues

La morue (*Gadus callarias*) doit être recherchée dans des eaux comprises entre 2 et 4 degrés C., aussi bien en hiver qu'en été.

L'utilisation du thermomètre de profondeur doit aller de pair avec la recherche au sondeur. Il est parfaitement inutile de rechercher la morue ailleurs. L'èglefin, par contre affectionne les eaux entre 5° et 6°C.

La morue s'est depuis 20 ans, considérablement raréfiée. Ceci tient au fait que la flotte de pêche Russe présente une expansion gigantesque de ses activités, soit sur les grands Bancs, soit au large du Groenland, que ses méthodes sont massives et organisées avec la précision d'escadres de combat, et que ses navires respectent en pêche une stricte discipline dans tous les rôles qui leurs sont assumés, et surtout dans la diffusion de renseignements aux navires du même pavillon. On ne peut en dire autant des pêcheurs français, farouchement individualistes et qui cachent à leurs partenaires l'importance des bancs rencontrés.

Les échos de morue sont facilement identifiables. Ils se présentent sous la forme successive de taches en forme de delta.

La figure 1 vous donne l'image de morues par un fond de 150 mètres. Elles sont extraites d'une bande continue de poissons qui s'étendait sur 42 milles marins. On voit le grouillement incalculable de morues que cela peut représenter.

Fig 1. Morues (cod).

Il faut constater que le chalut, avec sa modeste hauteur d'ouverture en pêche, qui est de 4 à 6 mètres, est un engin de capture dont le rendement est plus que médiocre, car le navire qui a rencontré ce banc à fait des prises de 7 tonnes pour 2 Heures de drague, soit sur une distance parcourue de 7 milles marins sur le fond, alors qu'en réalité, il a évolué parmi des milliers de tonnes de poisson, ce qui tend à appuyer la thèse que nous avons toujours soutenue, que les chaluts sont trop lestés, qu'ils raclent le fond, alors que la morue se tient au-dessus du fond et échappe en partie au chalut.

Thons

La figure 2 nous donne une détection de germon (*Germo alalunga*) presqu'en surface, entre 15 et 20 mètres. On constate la forme linéaire des échos du thon, comparables à des traces de fusées rapides. Ces échos sont facilement identifiables.

Lorsqu'un navire, recherchant le thon voit apparaître une image de thon isolé sur la bande de son sondeur, il doit immédiatement stopper et jeter l'appat vivant. Il

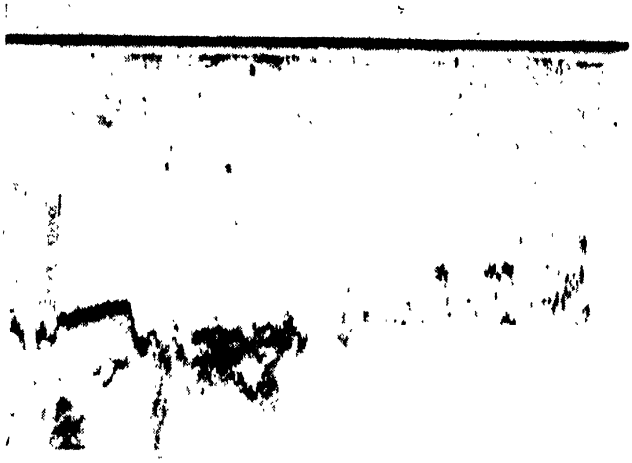

Fig 2a. Banc de thons (tuna).

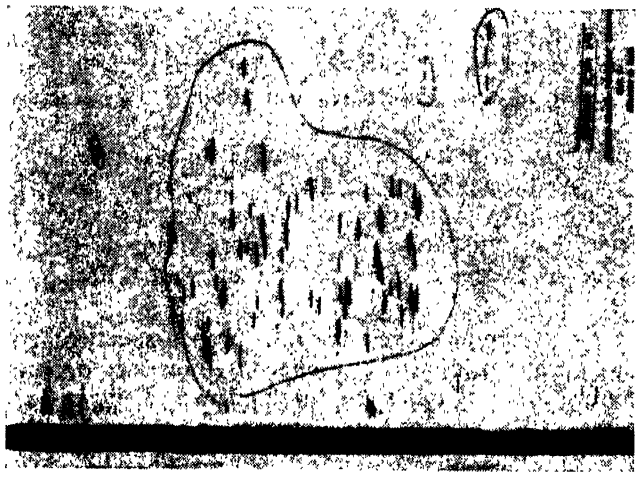

Fig 2b. Thons en bandes, écartés (tuna).

voit alors apparaître sur la bande le gros du banc qui monte eu surface et s'inscrit en quantité sous forme de fusées.

Sardines

Nous devons rappeler le rôle que joue l'influence du milieu sur le comportement des groupements de sardines. En premier lieu, l'hydrologie générale et ensuite l'hydrologie des zones de pêche, la température et la salinité.

Les pêcheurs, par des observations ataviques, sont au courant des zones littorales dans lesquelles ils ont l'habitude de rechercher la sardine (conditions météorologiques locales, vents qui ont une répercussion sur le niveau et la température des eaux côtières, phases lunaires, etc. . . .).

Mais avant les constatations permises par le sondeur à écho, ils étaient dans l'ignorance de certains facteurs sur les migrations et les mouvements quotidiens des bancs de sardines adultes.

Le sondeur nous a montré que les déplacements quotidiens se manifestent dans un espace restreint. Ce sont des mouvements de dispersion et de concentration.

Les migrations, qui entrainent les bancs d'une zone vers une autre n'excluent pas les phénomènes de dispersion et de concentration qui semblent donner à certains bancs le caractère d'un vol d'étourneaux.

Ces mouvements désordonnés des bancs de sardines ont accrédité dans l'esprit des pêcheurs la croyance à un simple caprice des sardines, qui semblent obéir à un instinct balladeur, alors qu'en réalité, l'action des facteurs extérieurs reste dominante.

Les remarques sur le mouvement quotidien des sardines dont les océanographes et biologistes de l'Institut des Pêches français nous ont révélé le caractère, sont dûes uniquement aux observations que leur a permis le sondeur ultra-sonore.

Grâce à leurs expériences, on a pu créer, chez les pêcheurs restés longtemps incrédules et sceptiques, un mouvement d'opinion favorable à la recherche des bancs de sardines par ultra-sons. Il est admis aujourd'hui en France, ainsi d'ailleurs, qu'au Portugal et au Maroc, que la détection par sondeur reste le seul procédé efficace pour l'amélioration de la pêche à la sardine.

Le sondeur à écho en vue de la recherche des bancs de sardines a été utilisé depuis 1951, d'abord au Maroc, sous l'impulsion de FURNESTIN, ensuite sur la côte Basco-landaise et les côtes Vendéennes par PERCIER, FAURE, KURC, de la TOURASSE, LETACONNOUX, MAURIN, NEDELEC et THIERRY. Nous ne reviendrons pas sur les résultats largement diffusés et qui ont donné les images des échos de sardines, d'anchois, de sprats, etc. . . .

Nous donnons ici, figures 3 et 4, des images de sardines méditerranéennes obtenues de nuit en Mai 1961 près de Collioure (fonds de 40 mètres) (Institut Scientifique des Pêches).

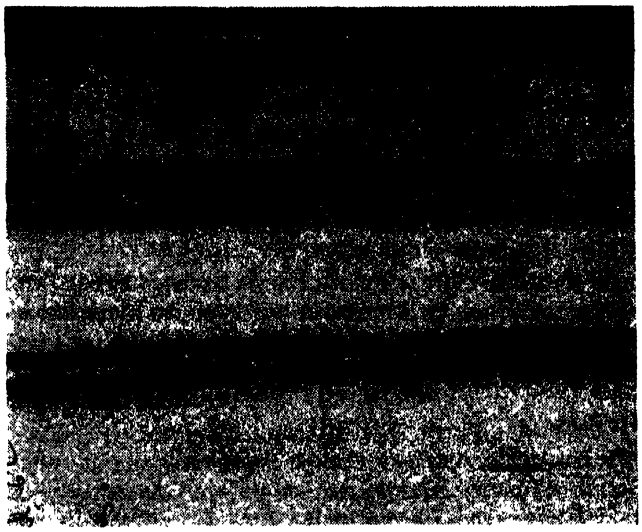

Fig 3. Sardines.

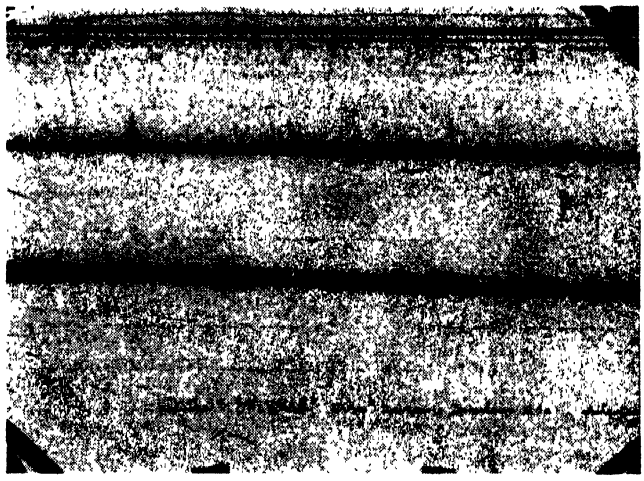

Fig 4. Célans, sonder CRM.

Harengs

Le sondeur à écho permet seul la preuve d'une distribution extensive des grands bancs. Les recherches avec le sondeur à écho ont permis de faire des estimations de la densité minimum des harengs (*Clupea harengus*) pour une pêche donnée et évaluée avec l'engin capteur utilisé.

On peut citer un bateau qui a pêché 80.000 Kgs de harengs dans le Seal Cowe, après avoir détecté la présence d'un banc de 9 mètres d'épaisseur à une profondeur permettant l'emploi de la senne. La senne ayant 60 mètres de diamètre, les harengs capturés occupaient 26,700 mètres cubes, avec une densité de 0,45 kilos pour 0,15 mètre cube d'eau. Ceci, devant être considéré comme une densité minimum, étant donné que les poissons qui se sont évadés avant la fermeture complète du filet ne sont pas compris dans l'évaluation.

Avec ce facteur de densité, il a été possible d'estimer la quantité de harengs enregistrée par le sondeur à écho. Le navire a pu déterminer qu'il franchissait des bancs de

harengs de 22 millions de kilos. Ce navire a enregistré sur son sondeur 40 bancs similaires, souvent presque continus, ce qui donnait, détecté par le sondeur, une présence de 880 millions de kilos de harengs.

Les bancs de hareng sont très faciles à identifier, étant donné l'image très visible de leur concentration sur les bandes du sondeur. Cette image se caractérise par son impression sur le papier en forme d'arbres, plus particulièrement de peupliers.

La figure 5, montre des bancs de harengs sur le fond, et l'on remarque en surface la présence du plancton qui conditionne les mouvements descendants diurnes ou nocturnes des bancs.

Merlans

Les bancs de merlans (*Gadus merlangus*) ne donnent jamais d'images imposantes et ils sont constitués par des petites taches éloignées les unes des autres situées à quelques mètres du fond.

La figure 6, montre des taches de merlans. Il arrive que la bande du sondeur présente quelquefois des images plus denses, mais on remarque alors facilement qu'il s'agit de bancs de merlans mélangés à des harengs ou autres espèces nageant l'un près de l'autre, et qu'en examinant la bande, l'image de leurs échos n'est pas la même. Le merlan seul, donne des images peu fournies.

Fig 5. Bancs de harengs (herring). Fonds de 35 à 40 mètres—Sondeur SCAM 610 Cie Radio-Maritime.

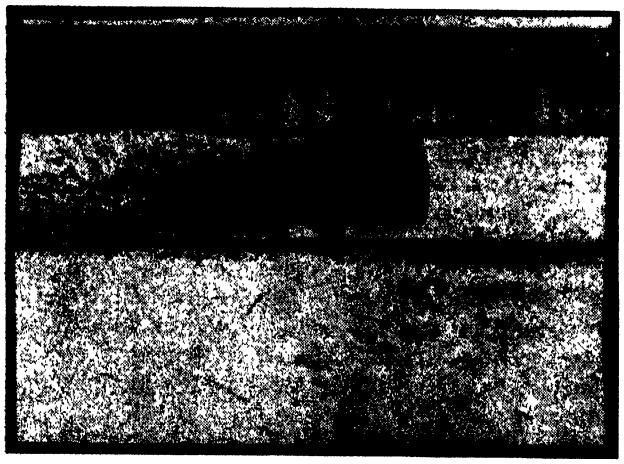

Fig 6. Merlans (whiting)—Fonds de 100 à 120 mètres—Chalutier Notre Dame de Boulogne.

Maquereaux

La figure 7, représente des maquereaux (*Scomber scombrus*). Cette espèce se présente toujours en quantité importante. Son image affecte la forme d'un dessin d'une forêt dense et continue dont quelques arbres dominent les autres. Le sommet des arbres est toujours plus noir, d'une touche plus dure. On note toujours la présence du plancton en masse au-dessus des bancs de maquereaux. Ces derniers peuvent s'étendre avec la même densité sur plusieurs milles de longueur.

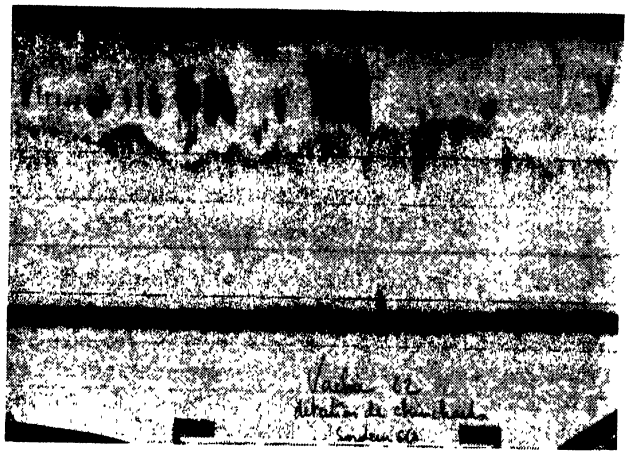

Fig 7. Maquereaux (mackerel)—Sondeur 610 CRM.

Merlus

Ce poisson est rarement détecté. On sait qu'en France, il est considéré comme une espèce noble et d'ailleurs chère à la vente. Le Port de La Rochelle est axé vers la pêche du merlus (*Merluccius merluccius*) et les bateaux rochelais le pourchasse inlassablement dans le Golfe de Gascogne. Remarquons que ces navires pêchent en moyenne 100 Kgs. au maximum de merlus par trait de chalut de 4 heures, soit 100 Kgs pour 14 à 16 milles parcourus par le filet sur le fond. Quand un chalutier ramène 2 tonnes de merlus au port après une sortie de 14 jours en mer (soit une pêche effective de 10 à 11 jours) on estimate cette quantité, une très bonne pêche.

La rareté de ce poisson est la clef du mystère de sa détection difficile, puisqu'il nage sur le fond, solitaire, à des distances fort éloignées les unes des autres.

Autres traces d'echogrammes

Les traces d'échos des figures 8, 9 et 10 montrent l'image caractéristique produite par les anchois (*Engraulus encrasecholus*), les chiens de mer et de gros poissons sur le fond.

Ligne blanche

Lorsque le poisson se trouve à proximité immédiate du fond de la mer et qu'il épouse les sinuosités de ce fond, il est souvent difficile de l'identifier avec certitude. L'Industrie met maintenant à la disposition du pêcheur un dispositif qui lève ce doute. C'est en réalité un "séparateur d'échos de fond", à qui on a donné la dénomination de "ligne blanche".

Il permet la discrimination graphique entre le profil du fond lui-même et les bancs de poissons qui évoluent ou sont statiques à son voisinage.

On obtient cette discrimination par le dédoublement de l'écho de fond à l'aide d'une ligne blanche séparatrice, qui épouse toutes les sinuosités du fond et permet alors au pêcheur d'avoir la certitude de la présence réelle du poisson. On voit donc combien ce perfectionnement peut lui apporter de précisions complémentaires.

Fig 8. Anchois (anchovy)—Bande de Sondeur Cie Radio-Maritime.

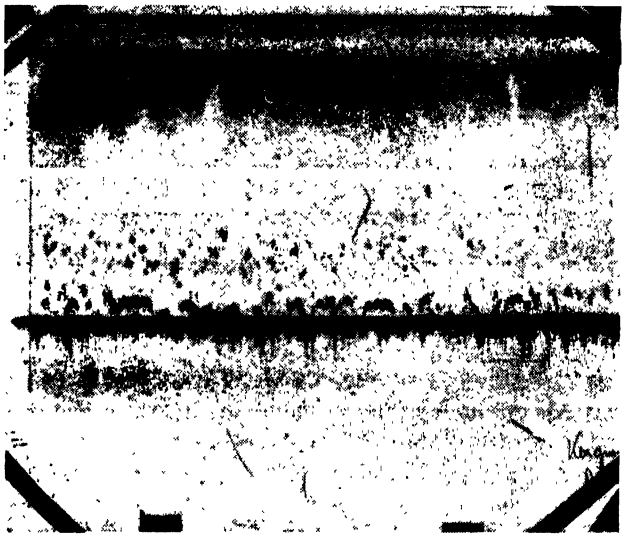

Fig 9. Chiens de Mer (dogfish)—Sondeur CRM.

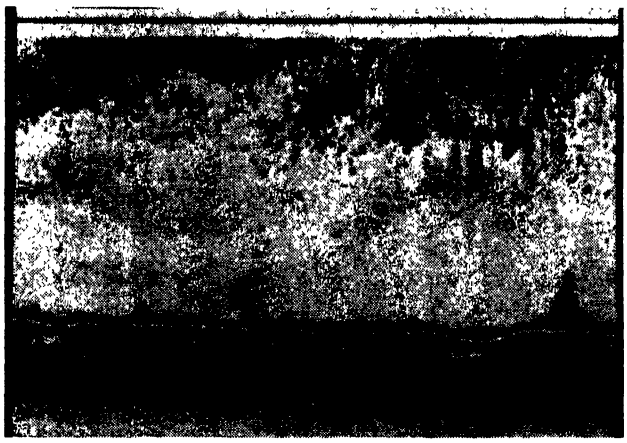

Fig 10. Gros poissons sur le fond et entre deux eaux—Fonds de 110 à 150 mètres Plancton en surface (big fish on bottom, plankton on surface).

Detection horizontale

Il s'agit de nouvelle possibilités offertes au pêcheur pour la recherche des bancs. Le navire n'a pas besoin d'être à la verticale du banc pour constater la présence du poisson, mais il peut le détecter à distance et déterminer le site du banc, sa hauteur de nage et la direction qu'il suit. L'Industrie française vient de mettre au point un appareil de ce genre qui trouve déjà de nombreuses applications à bord des navires de recherches et les grands chalutiers de tous pavillons.

La television sous-marine

Alors que la télévision proprement dite, connaît un développement mondial et nous donne même des images du Cosmos, les utilisations de la télévision sous-marine sont extrêmement limitées pour des raisons d'absorption du milieu aquatique marin. En plus de cette absorption, un halo dû à l'effet Tyndall dans les eaux troubles ou gluantes freine considérablement la portée utile des appareils.

Pour le moment, les appareils dont nous disposons permettent des recherches d'ordre biologique, des travaux de coques et de ports. Il est possible d'observer les engins de pêche en fonctionnement, on peut espèrer obtenir avec la télévision des renseignements pour un perfectionnement des engins de pêche, contrôler le comportement du poisson en présence d'un art trainant et ce même comportement dans le cul du chalut. La télévision sous-marine à un avenir incontestable dans les pêches maritimes, mais nous estimons que pour le moment, elle reste au stade expérimental pour la pêche courante et pratique. Il est cependant probable que dans les années qui vont suivre, nous enregistrerons de nouvelles possibilités offertes à l'industrie des pêches par la télévision.

Perspective d'avenir des sondeurs

Sur le plan industriel international, le marché des sondeurs ultra-sonores est assez étoffé pour permettre des études et des recherches de l'Industrie électronique, et tous les techniciens s'ingénient à apporter à ces appareils des améliorations constantes. Cette perspective est dûe surtout aux navires de pêche, dont le nombre très important autorise les efforts des chercheurs et des savants, puisqu'ils y trouvent une clientèle élargie.

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Echo-Detection of Tuna

Abstract

To fish for tuna scientifically, one must know tuna behaviour, swimming depth, speed and school density. Many methods have been used to gather these data, but have not offered sufficient conclusive evidence. In this paper, the author proposes use of an echo sounder. After many experiments, it has been established that an echo sounder can effectively detect tuna schools and contribute to tuna fishing. First, the author discusses the properties of an echo sounder able to detect tuna at a depth of 200 m, and concludes that the instrument must have a sounding depth of bottom of more than 3,000 m to operate efficiently. Secondly, data are mentioned on swimming depth, speed and school density, procured by echo sounders in the seas around Japan and in the South Pacific Ocean. These data establish that the swimming depth depends on the degree of illumination of the sky. The relationship between the shape of the banks in the grounds and the distribution of tuna is also explained. Finally, some examples of swimming speed and density of school are mentioned.

by
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Detection du thon par sondeur ultra-sonore

Résumé

La pêche scientifique du thon requiert des connaissances sur le comportement du poisson, la profondeur à laquelle il se déplace, sa vitesse de nage et la densité des bancs. Parmi les nombreuses méthodes employées pour rassembler ces données aucune n'a donné de résultats suffisamment concluants. L'auteur de la présente note propose d'utiliser à ces fins un appareil à repérer les poissons. De nombreux essais ont permis d'établir qu'un tel appareil peut effectivement détecter les bancs de thons et contribuer à la capture

ontinued from page 381

Cette émulation entre les industries électroniques internationales nous permet d'envisager des progrès et des possibilités de détection des poissons qui iront en se développant, surtout dans la détection horizontale.

Il existe également un procédé de détection acoustique. Dans ce domaine, non seulement les résultats acquis sont souvent décevants, mais ils exigent, pour poursuivre des études, des moyens financiers hors de proportion avec ceux dont dispose l'industrie privée. Les expériences poursuivies restent généralement de caractère confidentiel, étant exécutées à l'échelle des grandes puissances militaires navales. La menace que représente le sous-marin atomique est si grave qu'un effort considérable est actuellement fait pour accroître les moyens de détection actuels.

Les conditions de détection acoustiques sont intimement liées à la répartition des facteurs physiques caractérisant l'état du milieu marin, alors que la détection ultra-sonore s'en affranchit en partie.

Les techniques d'exécution des mesures qui affectent les propagations acoustiques sont encore à un stade rudimentaire, et elles échappent à l'industrie privée qui ne dispose pas d'un navire adapté et équipé pour de tels travaux. Outre l'équipement d'un tel bâtiment, il faut tabler pour assurer l'exploitation et l'archivage des données océaniques qui doivent être pratiquées sur une longue période, l'utilisation de ces données nécessitera un laboratoire à terre des plus complexes et des plus onéreux.

On peut donc, sans risque d'erreur, assurer les pêcheurs, que le sondeur ultra-sonore dont ils disposent, restera certainement l'outil le plus précieux et le plus efficace de la rentabilité de leurs navires pendant longtemps.

Conclusion

Nous avons donné les identifications des principales espèces commerciales pratiquement pêchées dans les Mers européennes. Il est entendu que ces types d'écho ne se retrouvent pas avec une netteté identique sur toutes les bandes de sondeurs d'origine différente. Le tracé pour un sondeur donné dépend de facteurs divers:

tension électrique appliquée
cadence de sondage du détecteur
vitesse de déroulement du papier enregistreur
sensibilité de l'appareil
densité et multiplicité des couches d'eau traversées
vitesse du navire.

Les images principales exposées ici, ont été obtenues avec un sondeur très sensible, mais il se peut que des appareils moins sensibles et moins modernes ne donnent pas des précisions aussi remarquables.

Nous ajouterons même que les expériences faites en 1954, par des océanographes, avec la plus scrupuleuse attention et probité, donnaient des images d'échos n'ayant plus de rapport avec celles obtenues aujourd'hui. Ceci tient uniquement au fait que la technique des sondeurs a été améliorée. On identifiait alors du gros thon rouge sous forme de points à peine visibles, alors qu'aujourd'hui le germon, plus petit, donne des images en fusées, facilement identifiables.

Les classifications des échos enregistrés à cette époque ne nous paraissent plus valables, avec les sondeurs actuels.

Sources

Les bandes de Sondeur ont été mises gracieusement à ma disposition par la Compagnie Radio-Maritime, l'Institut Scientifique des Pêches et la Société SCAM.

J'ai consulté mes confrères suivants: M. Von Brandt (Allemagne); M. J. Rawlings (Colombie); Mm. G. Kurc, Maurin, de Méglio, Percier (France); M. Hashimoto (Japon); Mm. de Espada, Manuel Rubio (Espagne); M. Aloncle (Maroc); M.Tibbo (USA) et j'ai eu aussi des contacts directs avec les Capitaines de pêche.

de ces poissons. L'auteur examine tout d'abord les caractéristiques d'un appareil capable de détecter les thons à une profondeur de 200 mètres, et conclut que, pour donner satisfaction, le dispositif doit pouvoir sonder à plus de 3,000 mètres. Il cite ensuite des données sur la profondeur de nage, la vitesse de nage et la densité des bancs, obtenues à l'aide d'appareils à détecter les poissons au large du Japon et dans le Pacifique Sud. Ces renseignements établissent que la profondeur de nage dépend du degré d'intensité lumineuse du ciel. Le document fait également état du rapport entre la configuration des bancs se trouvant sur les fonds de pêche et la répartition des thons. Enfin, l'auteur donne quelques exemples de vitesse et de densité des bancs.

Localizacion de atun mediante ecos

Extracto

Para la pesca con carácter científico del atún es necesario conocer el comportamiento de este animal, la profundidad y la velocidad a que nada y la densidad de los cardúmenes. Para recoger tales datos, se ha recurrido a muchos métodos, pero éstos no han ofrecido una prueba bastante concluyente. En este trabajo, el autor propone el empleo de un instrumento localizador de peces para realizar tales observaciones. Después de muchos experimentos, se ha comprobado que un localizador puede detectar eficazmente los cardúmenes de atún y efectuar investigaciones sobre éste. En primer lugar, el autor examina las propiedades de un aparato localizador que sirva para la detección de atunes a una profundidad de 200 m, y llega a la conclusión de que este instrumento, para funcionar eficazmente, debe tener una profundidad de sondeo de más de 3,000 m. En segundo lugar, se indican los datos sobre profundidad y velocidad a que nadan y sobre la densidad de los cardúmenes, obtenidos mediante fonolocalizadores en los mares que rodean al Japón y en el sur del Océano Pacífico. Estos datos muestran que la profundidad a que nadan depende del grado de iluminación del cielo. Igualmente se explica la relación entre la configuración de los bancos en las zonas de pesca y la distribución de los atunes. Por último, se mencionan algunos ejemplos de velocidad y de densidad de cardúmen.

TUNA schools are generally less dense than other schools. Consequently, to locate tuna, the acoustic power, pulse transmission, beam angle and sounding range must be properly selected. Also the observation of d.s.l. is important for forecasting tuna catch. The echo sounder must therefore have the capacity for d.s.l. detection.

The ultrasonic reflection loss of the fish body and of d.s.l. are known; the values are about 15 decibel at 28 kc, 8 db at 200 kc for yellowfin, and 20 db at 28 kc, 12 db at 200 kc for albacore. The reflection loss of d.s.l. is about 40 to 60 db within the range of 20 to 200 kc.

Fig. 1 shows the relationship of ultrasonic reflection loss of tuna versus frequency through 10 to 400 kc.

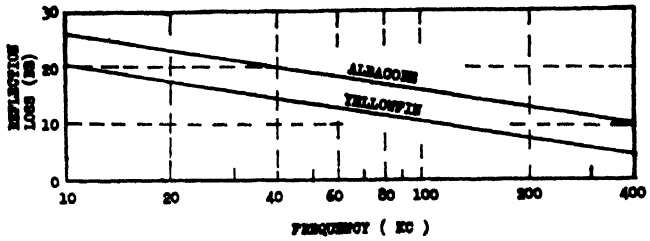

Fig. 1. Relation between frequency and reflection loss of tuna.

For tuna detection it is necessary to transmit a stronger output than for bottom or fish-school detection. For example, an echo sounder with bottom-sounding range of more than 3,000 m is required to detect tuna at a depth of 200 m.

The echo sounder used in the experiment was designed as follows:

Frequency 28 kc	
Ranges for recorder	(0 to 100 m) × 5 phases
	(0 to 120 m) × 5 phases
	(0 to 600 m) × 5 phases
for CRT	33·3/40 m
Transmitting system	valve oscillation
Output power	3 kW
Pulse transmission	90/75/15 per minute
Paper speed	21/17·5/3·5 mm/min
Transducer	AF alloy
size	163 × 270 mm
beam angle	11·5° × 8·2°
Maximum sounding capacity	6000 m
Maximum tuna finding capacity	500 m

Identification of fish appearing on the record of the echo sounder is important but difficult. An acoustic technique measuring the sound pressure of reflected wave from tuna, offers some solution. The kind and size of tuna can be roughly identified by measuring the sound pressure of reflected wave on the amplifier of the echo sounder, when the output acoustic pressure and also the reflection loss of tuna is known.

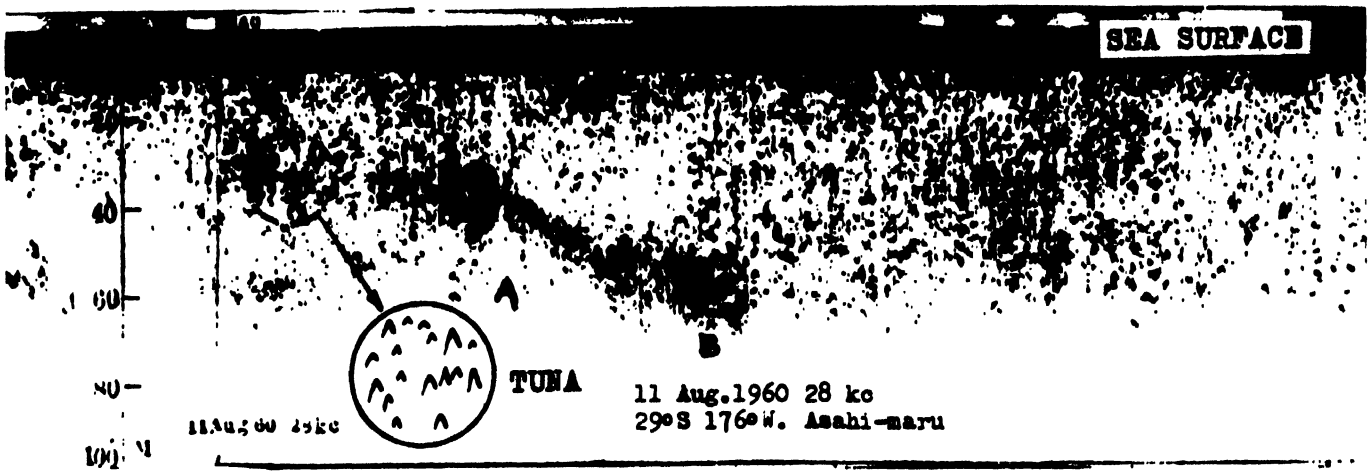

Fig. 2. Echo trace of tuna as recorded in New Zealand waters. Each triangle indicates a tuna.

Fig. 2 shows a record obtained on the fishing grounds north-east of New Zealand; each small triangle-like mark indicates a fish. Fig. 3 shows measured values of north-east of New Zealand; each small triangle-like intensity of fish which appeared on this echo chart. The abscissa indicates depth in metres, co-ordinate sound pressure in db. Mark (.) shows measured value for fish swimming in a deep zone of 20 to 100 m and which are recorded intensively on the paper and mark (x) indicates fish in the shallow zone. As the transmitted acoustic pressure of the echo sounder used in this measurement was known, drawing the curves of attentuation for different reflection loss from 15 to 60 db, these measured values show that they are closely within the range from 15 to 60 db. In other words, some of the echoes marked (.) with a value of 15 to 20 db seem to be albacore or yellowfin. The mark (x) seems to indicate small fish about the size of sardine or mackerel, as the value was not intense.

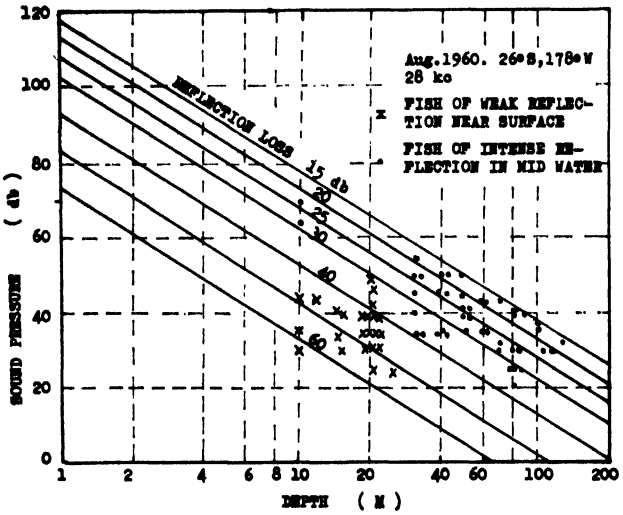

Fig. 3. Identification of tuna by acoustic measurement. Each curve indicates intensity of reflected wave from tuna or various reflection loss, and (.) or (x) show measured value for fish echoes.

Detecting tuna

Using the new type echo sounder, useful results were obtained in regard to tuna behaviour.

Fig. 4 shows the change of swimming depth of tuna. During the night, the recording paper of the echo sounder was filled with hazy echo-like d.s.l. and the trace of fish could hardly be seen in the deep zone. But in the morning about sunrise, the fish layer went slowly to 40 to 80 m. Towards evening the fish layer began to rise slowly at the speed of 20 or 30 m per hour, and fish were only recorded near the surface after sunset. During 17 days of experiment, this pattern of movement was found unchanged. Similar findings have been recorded in other areas.

The rising and sinking of tuna in the morning and in the evening respectively seems to be related to the illumination of the sky. The measured value for this illumination was noted in Fig. 4.

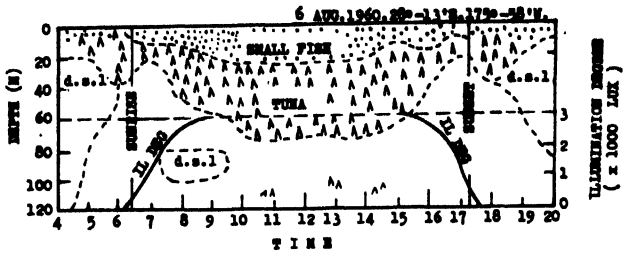

Fig. 4. Daily change in swimming depth of tuna, as recorded in New Zealand waters. Change of illumination degree versus time is shown.

Fig. 5. Distribution of yellowfin around school of small fish. This record was obtained in the sea east of the Solomon Islands.

The echo-chart in Fig. 5 shows the relationship between the depth of the tuna and the bait fish school. The small triangle in the deep 60-120 m zone indicates yellowfin (many yellowfin were caught in this area). The continuous black traces show dense schools of small bait fish.

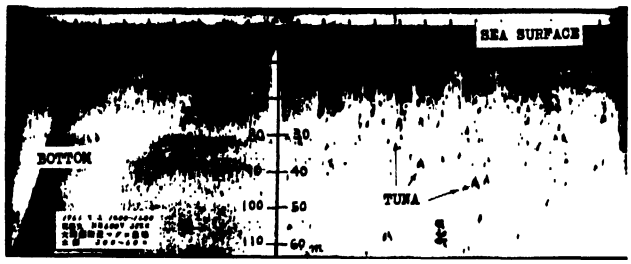

Fig. 6. Echo-chart of bluefin tuna in Tsugaru Strait. Each triangle is a tuna-echo.

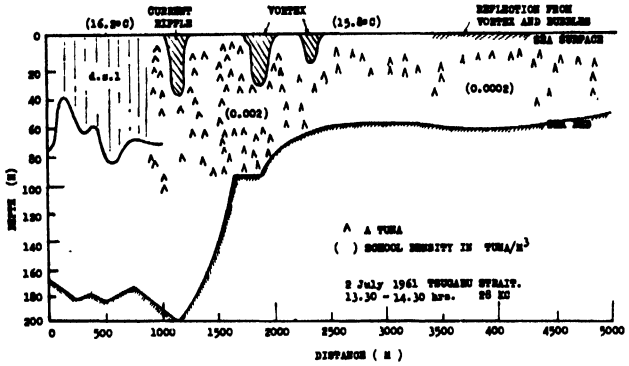

Fig. 7. Distribution of bluefin tuna around bank, obtained by continuous echo-chart.

In the fishing grounds of the bluefin tuna, in Tsugaru Strait, in the northern offshore area of Shimokita Peninsula, Aomori Prefecture, Japan, tuna gather

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Echo-Sounder Measurement of Tuna Longline Depth

by

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Abstract

Efficient tuna longline operation requires a thorough knowledge of the behaviour of tuna and the ability to gauge the depth at which the hooks operate. The depth of individual parts of a longline can be obtained by pressure gauge recording, but this does not enable the operator to form a clear idea of the shape of the longline as a whole.

The authors compared the echo-sounder recordings of longlines in operation with the data simultaneously obtained by pressure gauges and ascertained that a true configuration of the shape of the longline can be obtained by high-frequency echo sounding. Three types of echo sounder were used having frequencies of 28 kc, 50 kc and 200 kc. All parts of the gear were clearly recognisable on the records, as well as the difference in shape due to the use of different material in longline construction. The experiment further showed that a high frequency (200 kc) gives much better recordings than low frequency (28 kc).

Observation de la configuration de la longue-ligne du thon par le sondage a echo

Résumé

Pour l'utilisation efficace de la longue-ligne, une connaissance approfondie du comportement des thons est nécessaire, mais il faut aussi avoir la possibilité de mesurer la profondeur à laquelle opèrent les hameçons. Or, si l'on peut actuellement mesurer en certains endroits, la profondeur de la longue-ligne, la méthode employée ne permet pas de se faire une idée précise sur la configuration de la ligne submergée.

Les auteurs ont comparé les sondages de la longue-ligne en opération, enregistrés par écho-sondeur, avec les renseignements obtenus simultanément par des indicateurs à pression. Cette comparaison a confirmé qu'il est possible de connaître, par l'enregistrement d'écho-sondage, la forme exacte prise par la longue-ligne en opération. Les expériences effectuées à l'aide de trois fréquences différentes: 28 kc, 50 kc et 200 kc, ont permis d'identifier aisément toutes les parties de l'engin et d'observer la configuration de ces diverses parties construites de matières différentes.

L'expérience a aussi démontré que, pour ce travail, l'écho-sondeur à haute fréquence (200 kc) donne de meilleurs résultats que celui à basse fréquence.

Empleo de la ecosonda para determinar la profundidad a que estan los palangres atuneros

Extracto

Para que los palangres atuneros den buenos resultados es necesario conocer a fondo el comportamiento del atún y poder determinar a qué profundidad se encuentran los anzuelos. La profundidad de partes individuales de un palangre puede determinarse registrando la presión en un manómetro, pero con esto el pescador no se puede formar una idea clara de la forma que tiene el palangre en su conjunto.

Los autores compararon registros obtenidos con ecosondas de palangres calados con datos recogidos simultáneamente con manómetros de presión y determinaron que puede conocerse la forma exacta del palangre mediante ecosondajes de alta frecuencia. Emplearon tres tipos de ecosondas con frecuencias de 28, 50 y 200 kc. Todas las partes del aparejo se reconocían fácilmente en los registros y también se observaban las diferencias presentadas por el palangre a causa de los diversos materiales empleados en su fabricación. El experimento también demostró que una frecuencia alta (200 kc) da registros mucho más claros que una frecuencia baja (28 kc).

HITHERTO, water pressure gauges have generally been used to measure the depth of the longline; but shape of the line cannot be so determined during fishing operations.

The echo sounder used in this experiment operated with 28, 50 and 200 kc ultra-sound; some of the main

continued from page 384

around the bank of Oma. Fig. 6 shows an echo chart obtained by using at 28 kc echo sounder, and each triangular mark indicates bluefin tuna. The depth of the sea bed changes steeply from 200 m to 60 m as shown in Fig. 7. Tuna were distributed in a wide area, the distribution being especially dense at the steep incline. The depth of the tuna was measured at about 100 m in the deep zone and at a few metres in the shallow zone.

Swimming speed of tuna

The swimming speed of fish may be calculated from the echo trace appearing on the recording chart of the echo sounder. When the ship speed is known, the swimming speed can be calculated from the height and width of the fish echo.

It was thus calculated that the maximum speed in normal conditions was within the range of two to three knots for yellowfin, albacore and bluefin respectively.

Density of the school can also be calculated from the echo-chart. The calculation was based on the supposition that the beam of sound was a circular cone, and the beam angle a half-power beam angle for the combined directivity of transmitting and receiving transducer.

The calculated values show the density of tuna schools was as follows: for albacore in the Southern Pacific Ocean, 0·0002 to 0·0003 tuna/m^3, for yellowfin, 0·0001 tuna/m^3, and for bluefin tuna along the Japanese coast 0·0002 tuna/m^3 (maximum 0·002 tuna/m^3).

Because of the echo sounder's value in tuna detection new efficient fishing methods are to be developed.

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1. Hashimoto, T. and Y. Maniwa, Technical examination and tentative making of fish finder for tuna and experiment on it on sea. *Tech. Rep. Fish. Boat.*, 13:103-111. 1959.
2. Nishimura M., Study on echo sounders for tuna fishing in the north-eastern New Zealand Sea. *Tech. Rep. Fish. Boat.* 15:78-89. 1961.

features are shown in Table I. In this experiment, depth-recorders based on water pressure[4] were also used at the same time for comparative data. The initial experiments were made at Towada Lake (depth 340 m) because of the relative absence of waves, currents and wind; but the operational experiment was made at Sagami Bay under normal ocean conditions.

Ultrasonic reflection of longline

A knowledge of the longline's ultrasonic reflection loss is necessary to adjust the echo sounder for longline detection. The longline used in the test was slightly longer than the diameter of the ultrasonic beam as shown in Fig. 1, and it was suspended horizontally in the water. The first experiments were made to measure the echo margin of the rope at three different frequencies, and the reflection loss was calculated from the echo-intensity of a standard reflector with a constant reflection loss. The longline was made of polyvinyl No. 20×55×3×3, 5·7 mm diam, coated with coal tar.

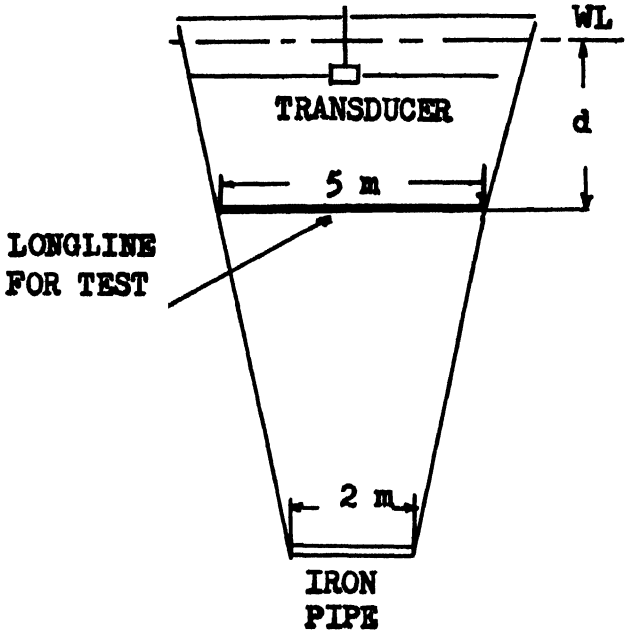

Fig. 1. Measuring method of reflection loss.

Table I	NTL 500 Type	NTB 500 Type
Frequency (kc)	28	50/200
Sounding range (m)	(0—50)×5	(0—50)×5
	(0—75)×5	(0—75)×5
	(0—100)×5	(0—100)×5
Beam angle	13°	13°/3·8°
Sounding capacity (m)	4,000	1,000/500

The reflection losses measured were 46 db at 28 kc, 44 db at 50 kc and 41 db at 200 kc. Fig. 2 shows the relationship between the frequency and reflection loss; it seems that the reflection loss decreases when the frequency increases for the range of 28 to 200 kc. The maximum longline detection capacity based on the values given above was calculated for the apparatus (Table I) as 250 m for 28 kc, 90 m for 50 kc and 200 m for 200 kc.[5]

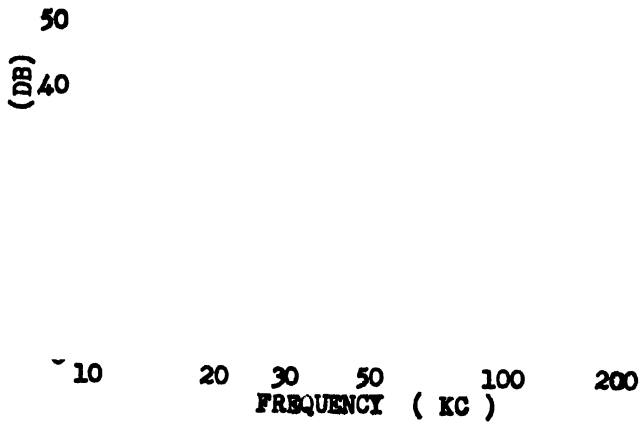

Fig. 2. Relationship between reflection loss and frequency.

The reflection loss tends to increase under low-frequency, when the inclination of the longline increases. Comparing recordings obtained by 28 kc and 200 kc sounders, (Fig. 3) it is apparent that longline detection is better with high-frequency than with low-frequency.

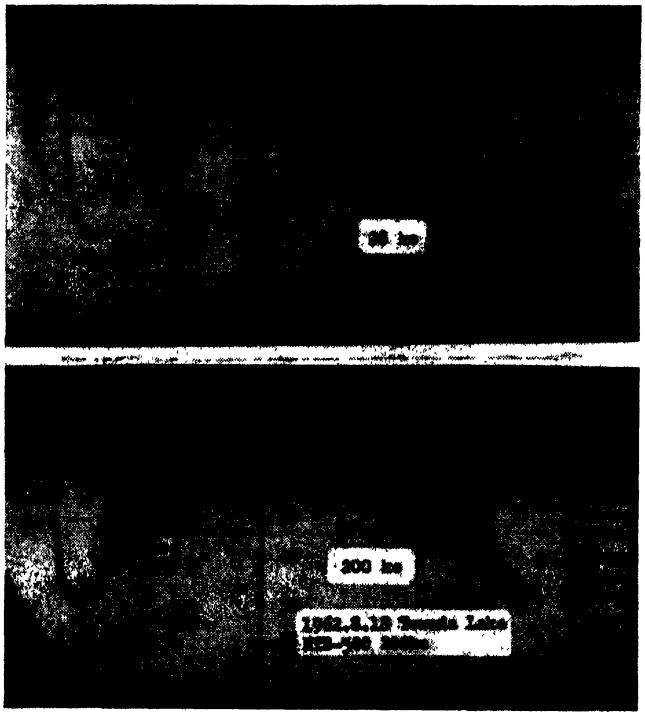

Fig. 3. Comparison of echo chart of longline obtained by 28 kc and 200 kc.

Reliability of longline echo recordings

The shape of the sea bottom can be accurately recorded by echo sounder, when the beam of the ultrasound transmitted by an apparatus is extremely narrow.[6] Accordingly, 3·8° was taken as the beam angle of the 200 kc echo sounder used in this experiment, resulting in the shape of the longline being recorded without error. To verify this further experiments compared the depth of the longline as obtained by echo sounder with that

obtained by pressure depth recorders attached to the first third and fifth junctions of branchlines.

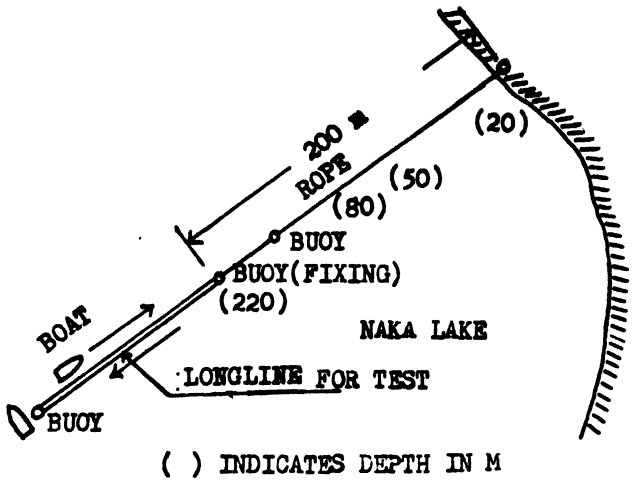

Fig. 4. Method for testing the reliability of depth measurement.

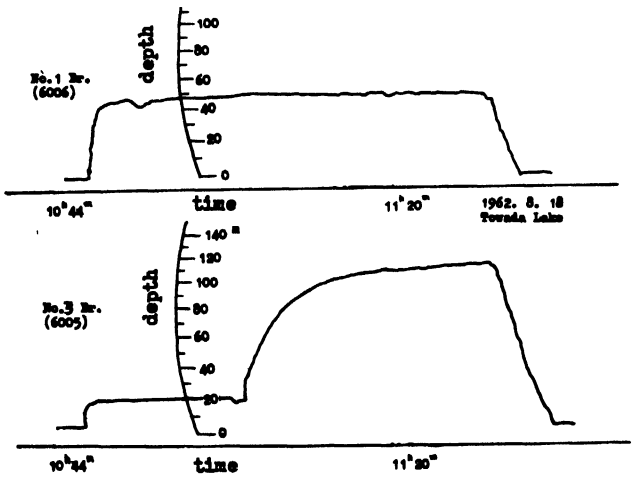

Fig. 5. Depth indicated on the depth recorder.

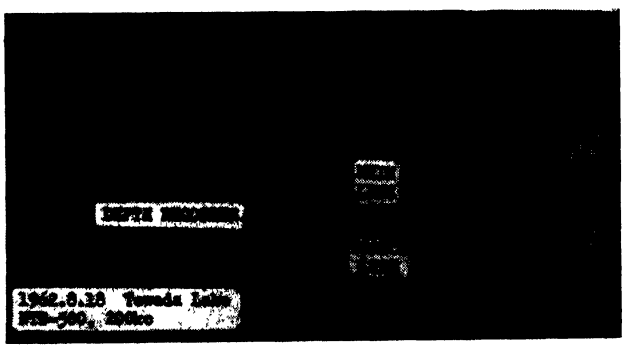

Fig. 6. Depth indicated on the echo chart.

One basket of longline was set in a fixed position as shown in Fig. 4. A recording by echo sounder was obtained by running over the longline at constant speed. Fig. 5 shows the record of the pressure depth recorder, while Fig. 6 gives the recording of the echo sounder.

As the scale ratio of the ordinate (depth) and the abscissa (distance) of these recordings are not proportionate, the readings were converted and are given in Fig. 7 on an identical scale basis. In this figure, the points marked with an x give the depth at the junctions of snoods No. 1, 3 and 5 with the mainline as measured by the pressure depth gauges and it can be seen that these depths almost coincide with those obtained by the echo sounder. Based on this it may be safely assumed that when a sufficiently narrow acoustic beam is used, the operational shape of the longline can be measured accurately.

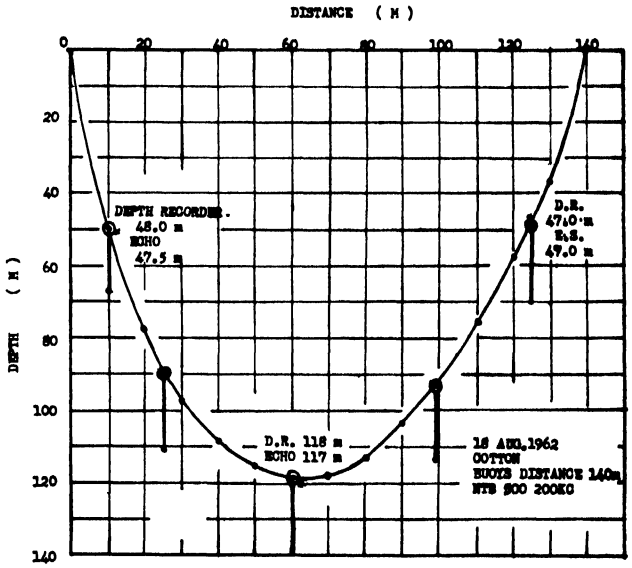

Fig. 7. Shape of longline obtained by echo sounder and depth obtained by depth recorder.

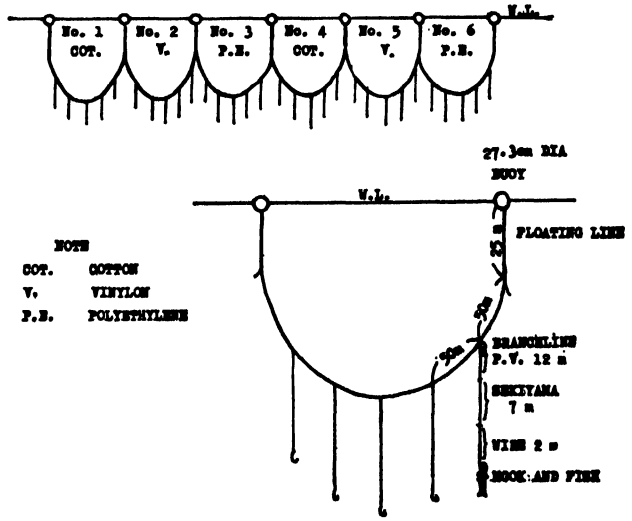

Fig. 8. Construction of longline used for detection.

Shape of longline of differing material

To investigate the effect on the operational shape of the longline when made of materials of different density, a section of longline was assembled as shown in Fig. 8.

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A 200 kc/28 kc Dual Frequency Echo Sounder for Aimed Midwater Shrimp Trawling

by

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Abstract

A remarkable development in midwater shrimp trawling has taken place since the winter of 1959 in the East China Sea. By the application of a dual frequency echo sounder, with 28 and 200 kc/s ultrasound, connected to two transducers on the headline and by using specially designed trawl gear, it was possible to operate successfully on compact shrimp schools swimming in midwater. The ship's transducer records the depth at which the schools swim at the time the ship passes over, while the net transducers give accurate information on the position of the net in relation to the bottom and surface. This makes it possible to lower or raise the net into the water layer of the school and to conduct "aimed" fishing. The trawl nets used by 700–800 hp sidetrawlers are of the four-seam type with a 44 m headline and 55 m footrope, made of black polyethylene knotless netting. Curved otter boards of the Suberkrüb type 3·2 m high and 1·6 m broad are used with these nets. Full specifications and design drawings are given of the nets and the otter boards. A successful shrimp fishery of about 200 trawls is presently using this gear.

Un echo-sondeur a deux fréquences (200kc/28kc) pour la pêche pelagique aux crevettes

Résumé

Au cours de l'hiver 1959, la pêche pélagique des crevettes s'est développée de façon remarquable dans la Mer de Chine orientale. Par l'application d'un écho-sondeur à deux fréquences, avec des ultra-sons de 28 et 200 kc, relié à deux émetteurs montés sur la ralingue supérieure et par l'utilisation de chaluts spéciaux, il a été possible d'opérer avec succès sur des bancs compacts de crevettes, entre deux eaux. L'émetteur du bateau enregistre la profondeur du banc de crevettes au moment où le bateau passe au-dessus, tandis que les émetteurs de la ralingue supérieure donnent directement la position du filet par rapport à la surface et au fond. De cette manière, il a été possible de lever ou d'abaisser le filet dans la couche d'eau et de pratiquer la pêche "visée". Les chaluts utilisés par les chalutiers pêchant par le côté de 700–800 cv sont du type à 4 coutures, avec des ralingues supérieures de 44 m et ralingues inférieures de 55 m, construits entièrement de polyèthyléne noir, en filet sans noeuds. Des panneaux courbés du type "Suberkrüb" de 3,2 m de hauteur et 1,6 m de largeur sont utilisés avec ces filets. Les caractéristiques et dessins de ces engins sont donnés dans la communication. A présent, 200 chaluts environ, utilisent cen engins avec succès.

Una esconda de frecuencia doble de 28 y 200kc para la pesca dirigida del camarón con artes de aurastre flotantes

Extracto

Una notabilísima innovación en la pesca del camarón con artes de arrastre flotantes se puso en práctica en el invierno de 1959 en el mar del Este de la China. Aplicando una ecosonda de frecuencia doble de 28 y 200 kc/seg conectada a 2 transductores en la relinga alta y empleando un arte de arrastre construído especialmente, se pudieron explotar con gran éxito cardúmenes compactos de camarón que nadaba entre dos aguas. El transductor del barco registra la profundidad a que se encuentra el cardumen en el momento en que el barco pasa por encima, en tanto que los transductores de la red indican exactamente cuál es su posición con respecto al fondo y a la superficie, lo que hace factible elevarla o

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Each unit was alternatively made of cotton, vinylon and polyethylene. The line was first operated at Towada Lake for observation and a recording was taken 15 minutes after setting.

This shows that all parts of the gear, mainline, branchline, sekiyama and hooks, were clearly recorded. As this section of six units was set isolated, the outer ends, units one and six closed in under their own weight and the hook and bait of the centre branchline sank to a depth of 143 m.

Unit three was made of polyethylene which has 0·95 density and was therefore only submerged by the weight of the sekiyama and hook. The centre hook of this unit only sank to 77 m, while the distance between the floats remained much greater. The hooks of unit two which was of vinylon material, attained a maximum depth of 115 m.

The experiment was repeated at sea during average weather and recording was obtained 15 minutes after setting. The gear again consisted of six units rigged as before and the different parts of the longline are well discernible in spite of rough seas.

The test showed that a clear record of longlines and all connections can be obtained by high-frequency (200 kc) echo sounders.

Such measurements are very much the same as those obtained by pressure gauges, but an echo sounder records more accurately the true shape of the longline.

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5. Hashimoto, T. and Y. Maniwa: Technical examination and tentative making of fish-finder for tuna and experimenting with it at sea. Tech. Rep. Fish. Boat., 13:103-111. 1959.

6. Hashimoto, T. and M. Nishimura: Reliability of bottom topography obtained by ultrasonic echo sounder. Inter. Hydrographic Rev. XXXVI-1:43-50. 1959.

bajarla que esté en la capa de agua donde se encuentra el cardumen y practicar de esa manera la pesca "dirigida". Los artes usados por los arrastreros con motores de 700 a 800 hp, que pescan por el costado, son de 4 relingas, con la alta de 44 m, la baja de 55 m y se hacen de polietileno negro sin nudos. Con éstos se emplean puertas curvadas del tipo Suberkrüb, de 3,2 m de altura y 1,6 m de longitud. Se dan detalles completos e ilustraciones de las redes y las puertas, empleadas actualmente por 200 arrastreros dedicados, con excelentes resultados, a la pesca del camarón.

IN the winter of 1959 the development of a dual-frequency echo sounder for trawl fishing in the East China Sea remarkably increased the catches of prawn (*Penaeus orientalis* Kishinouye). Subsequent exploratory fishing using it provided information on the behaviour and reactions of bottom fish to a net, the diurnal vertical movement of the dsl and the close relations between the dsl and the bottom fish which had been reported. In early observations of the trawl net by echo sounder, a second boat equipped with an echo sounder had to be used which would follow the trawler, just above the net to observe the performance of the net towed by the first vessel. This often resulted in erroneous measurements when the echo-sounding vessel was slightly out of line as she would often obtain no echo at all or receive echoes of parts of the net other than the actual headline bosom, resulting in higher or lower readings.

Early use of the netzsonde improved measurements of the net height to some extent. With this method, a transducer mounted on the headline emits and receives ultrasound from sea surface and the bottom; the transducer itself is connected through a cable to the recorder installed on the fishing boat. Under normal operation the fisherman on board can clearly detect the height of net mouth, the distance from the bottom and fish entering the net. If the sea bed is rather flat, the net can be towed near to the bottom, but on uneven bottoms, the record becomes too complicated to measure the height of net. The authors found that by combining the netzsonde with another echo sounder on board it was possible to adjust the towing depth to the swimming layer of fish. Many of more or less similar attempts proposed in various countries employed only one transducer on the net.

Fig 1. Echo chart showing a large school of the prawn, Penaeus orientalis *Kishinouye, that rose from the bottom of the Yellow Sea at dusk on January 9, 1962.*
Depth of waters 75 m, the highest layer of the school 44 m and the lowest layer 7 m, above the bottom.

The echo sounding records taken in the East China Sea in depths of 60 m indicated that the prawn schools usually swim about 10 m above the bottom, but that this swimming layer often rises to 30 or 40 m from the bottom (Fig. 1). This movement of the prawn in relation to the bottom makes it necessary to have a device on the net to accurately indicate its depth. As a result the Net-Vision (Japanese patent pending) was designed, tested, and has now come into service on more than 100 fishing boats operating midwater at night, as well as in the daytime. Much assistance was obtained from Hamuro and his colleagues who designed the midwater trawls (Hamuro and Ishii, 1960) on which the experiments with the present device were carried out. Japanese and Canadian patents are pending.

Construction and operation of Net-Vision

The apparatus consists of a dual-frequency echo sounder with a transducer installed on the fishing vessel, an electrical connection cable and two transducers for mounting on the headline (Fig. 2). The net transducers are housed, water and pressure tight, in a metal box of 140 X 330 X 125 mm in size of which the weight in water is 9 kg.

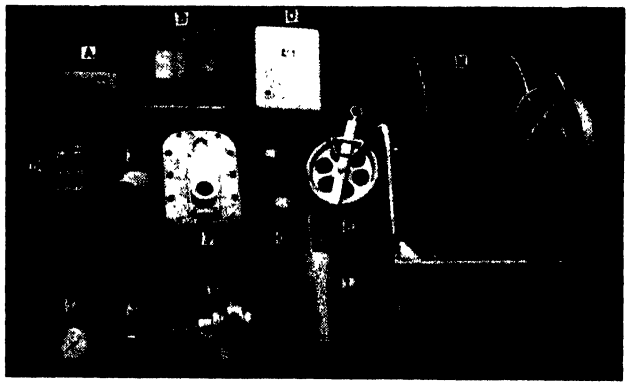

Fig 2. Component parts of the Net-Vision, model NV 4-500, under report. A. Switch board; B. main body housing the paper indicator, oscillograph, and amplifier; C. pulse transmitter; D. spare box and recording paper containers; E. invertor; F. net-side transducer; G. boat-side transducer; H. pulley; I. oil pressure gauge; J. flow control valve; K. hydraulic pump; L. oil tank; M. cable reel with a motor for the pump.

The two transducers are installed on the headline in such a way that the one faces up towards the surface and the other towards the bottom. The surface transducer emits an ultrasound beam of 28 kc and 75 kc, or 200 kc towards the sea bottom.

The upper transducer has a beam angle of at least 110°. The box containing the transducers is fastened on to the headline and connected to a five-core electric cable made in lengths of 800 m, which extends along the wings of the net to a suitable reel at the stern of the vessel. (The length of the cable veered out is about 5 per cent longer than the warp length normally used.)

The terminal of the electric cable is electrically connected to a slip ring mounted on one side of the reel; a water-tight brush connector runs over the slip ring and

connects the transducers to the transmitter receiver and indicator of the echo sounder. With the circuit closed the cable resistance is constant and the cable can be freely paid out or hauled in during the operation. The echo sounder on board has two frequencies, 50 kc and 200 kc and is capable of sounding up to 500 m with a maximum electric power for the transducer at a level of about 3 kW. The indicator of the echo sounder records two series of information at the same time; i.e. the echoes received direct from the bottom giving the water depth under the boat, the other giving the position of the net in relation to the bottom and the surface; these two indications can be received either independently of each other or simultaneously. The instrument furthermore provides for obtaining echoes from the net transducers on the screen of the cathode ray oscillograph.

Laboratory tests on the pressure range which the net transducers can sustain have proved that they can endure a pressure up to 50 atmosphere corresponding to an underwater pressure of 500 m depth. Detailed specifications of the apparatus are given in Table I.

Table I Major specifications of the Net-Vision, Model NV4-500, under report

	NTB-500 (On boat side)	NV4-500 (On net side)
Sounding range of paper recorder (m)	Shallow 50 Middle 75 Deep 100 } X5	Maximum depth tested 250m Cable length tested 1200m
Range of cathode ray oscillograph (m) (tube diameter 127mm)	Shallow 17 Middle 25 Deep 33	Can be switched to and from boat transducer
Frequency of ultrasound (kc)	50 or 200 at choice	28 for upward transducer 75 for downward transducer
Beam Angle	13°(back and forth) 26°(left and right) 76°(conical) 50 kc 22° for 200kc	110°for 28kc,flat projection 47°for 75kc,conical projection

Pulse transmission, (per minute); Shallow range 900, middle range 600, deep range 450.
Recording system; Straight line indication.
Recording paper; Wet type, length 15 m, width 150 mm.
Paper speed (mm/min); Shallow range 42, middle range 28, deep range 21.
Time notch intervals; 1 minute.
Power supply (V); D.C. 24, A.C. 100 or 200.

Performance

Three transmissions of ultrasound follow each other closely from the headline and ship's transducers. The moment the ship's transducer has transmitted towards the bottom, the upward transducer on the headline transmits towards the surface. When the echo of the upward headline transducer returns, the downward transducer on the headline transmits towards the bottom.

With the vessel operating in 75 m depth and the headline situated at 25 m above the bottom the sonic functions will be as follows: as the sound velocity in sea water is about 1,500 m/sec the first pulse of ultrasound emitted from the ship's transducer to the bottom returns in one-tenth of a second covering the total distance of 150 m for both directions. The first emission from the net transducer to the surface returns in one-fifteenth of a second having covered a distance of 100 m. The second wave from the net transducer towards the bottom returns in one-thirtieth of a second covering a total distance of 50 m, so that the total time required for the net transducer's emission and registration of echoes is one-fifteenth plus one-thirtieth is one-tenth of a second, which is the same as that needed for the emission and return of the ship's wave.

The same principle of synchronisation in performance is applicable to any depth of water within the range of the echo sounder. The echo sounder therefore constantly indicates a true position of the movements of the net in relation to the bottom. The two patterns made by the bottom echoes, the one received from the ship's transducer and the other from the downward directed headline transducer can be recorded on paper of the same proportional scale, showing corresponding positions to each other. In the East China Sea operating with 800 m of warp out, it was found that the patterns of the bottom recording obtained by the ship's transducer and the downward directed headline transducer agreed to within one per cent. Where the bottom is rough the two indications of the bottom can be obtained separately by switching over from one recording to the other.

Observations of gear behaviour

A number of experiments using the Net-Vision, model NV/4-500, were conducted in 1960 and 1961 in co-operation with several leading fisheries firms in Japan. For studying the behaviour of a trawl in operation the essential factors include the size of the net, the warp length and the speed of towing or propeller rpm in addition to many other pertinent conditions. Where it concerns the behaviour of a pair-trawl, the distance between the two vessels is one of the main factors. Much, however, can be observed in regard to the behaviour of trawls at various depths by the study of echo-sounder records, and the following discusses the records obtained during one of the above mentioned trial experiments carried out in co-operation with the Yamadaya Fishing Company, with *Yamada Maru No 12* in the East China Sea during August 1962.

The net used had extra large bouyancy and was operated with only about half the warp length used for the traditional trawls.

Towing close to the bottom

Fig. 3 shows an example of the echo record obtained when towing the trawl close to the bottom in 61 m depth of water. On the left of the echogram the opening height of the net is 8·5 m (from footrope to headline), while the distance between the footrope and the bottom is 9 m. This distance kept constant as long as the engine revolutions were kept at 300 rpm. During the experiment the engines were stopped for about two minutes and this can clearly be seen towards the middle of the echogram where the headline rises about 3 m while the footrope gradually sinks to the bottom.

With the vessel stopped the vertical opening of the net reached 20 m with the footrope on the bottom. As the vessel picked up speed again the headline was suddenly pulled downwards while the footrope was lifted and was then towed at about 50 cm above the bottom.

Fig 3. Traces of net towed a little above the bottom with the propeller rpm at 200 to 210 rpm. Depth of waters: 61 m.

Midwater trawling

Fig. 4 shows the vertical movement of the gear as recorded on the echogram when the rpm of the engine were slowly changed. Looking at the traces of the net from left to right on the echogram, it can be noticed that the vertical net opening was 6·5 m with the engine working at 280 rpm. At 300 rpm the vertical opening becomes 5·5 m while the headline rises to 37 m above the bottom. The vessel was then stopped and as can be seen towards the right of the echogram, there is a sudden rise of the headline followed closely by a gradual lowering as the net sinks to the bottom. It can also be observed that the footrope sinks much faster than the headline.

This echogram shows how clearly Net-Vision indicates the various movements of the gear in operation and points to its many advantages for fishing in midwater.

Fig 4. Traces of the net towed at 280 to 300 rpm. Panel A shows reflections received only from the net transducer. Panel B shows reflections received from both the boat and the net transducers. The headline when rising to its highest is 37 m above the bottom.

Bottom trawling

Experiments were undertaken with the same gear used during the above experiments, to ascertain whether such gear, using a much shorter warp than the traditional trawl, could also be used for bottom trawling. In Fig. 5 the echogram shows that when the trawl operated with a footrope 4 m above the bottom the vertical opening was 9 m, with the engine running at 220 rpm. As the rpm of the engine is decreased to 180 rpm it can be seen that the footrope gradually approaches the bottom while the vertical opening increased to 11 m.

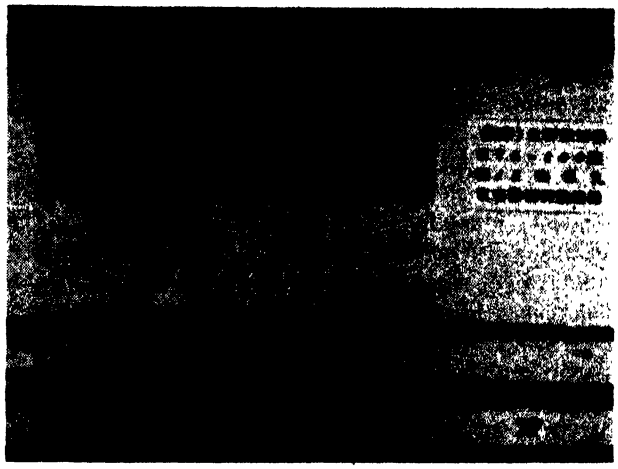

Fig 5. Traces of the net towed along the bottom at 220 to 180 rpm.

Observations of gear and fish

The name Net-Vision was given to the apparatus because the entrance of fish to the net can clearly be detected on the screen of the cathode-ray tube, as well as the changes in the vertical opening of the net.

The height of the net mouth can also be seen precisely and continuously with reference to the scale printed on the screen itself. Fig. 6 gives an example of the cathode ray flashes as seen on the screen and the wide flashes in the upper (A) and lower (C) parts of the screen indicate the position of the head and foot ropes respectively.

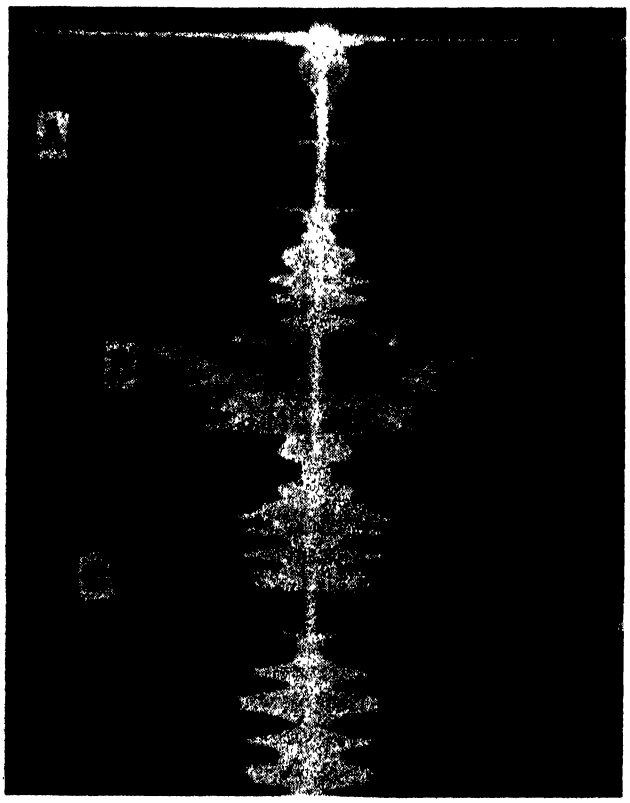

Fig 6. Traces of a school of the prawn entering the net as seen on the screen of the cathode-ray tube. Height of the net mouth: 7·5 m. A. Headline; B. Prawn entering the net; C. Footrope.

The opening of the net mouth in the illustration is 7·5 m and the broadening flashes at the centre represent a school of fish passing into the net mouth; the intensity and amplitude of the flash gives an indication of the density of the school.

The sensitivity of the cathode ray oscillograph is higher than that of the paper recording system and the ultrasonic reflections on the screen are more reliable for indicating fish schools than the traces on the recording paper. With more dense schools of fish, for example, the flashes may fill the full width of the screen which measures 127 mm from side to side. With very dispersed schools on the other hand, the echoes may narrow down to only 1 mm across the centre line of the screen, so that between these two extremities there is a range of 1 to 64 for estimating the density of the school. The flashes on the screen have a rate of 40 decibels between their maximum and minimum amplitude.

The cathode ray oscillograph, furthermore, gives more detailed and accurate information concerning the movement of the footrope in respect of the bottom contour.

The Net-Vision can be of much assistance to the fishermen in ascertaining the abnormal conditions in the operation of the gear such as entanglements (Fig. 7). By installing transducers to transmit ultrasound horizontally at appropriate points of the net mouth, the opening width of the gear can be measured in the same way as was described for the height.

With special reference to the use of the instrument in surveys, the senior author could observe that in the East China Sea the diurnal migration of the dsl is closely related to the changes in luminosity of the deeper water layers as they occur at various times of the day. By holding a photometer northward, he found that during the daytime the luminosity was 7,000 Lux. At sunset the luminosity suddenly decreased from 1,000 to 250 Lux at which time the echo sounder indicated the dsl emerging fast to the deeper water layers and dispersing. This phenomena was often followed by indications of big quantities of fish.

In the last few years, the application of a dual frequency echo sounder with 200 kc ultrasound (wave length 7·5 mm) has corrected the long-held but misguided view of the Japanese fishermen that fish schools scatter at night.

The above has led to "aimed" fishing, by which is meant that the gear is manoeuvred into the layer of water containing the fish which have been detected by the traces on the echogram from the ship's transducer. This can be done either by veering or hauling the warps or by changing the engine speed, or by a combination of these methods. As alterations of the warps normally take longer to raise or lower the net, preference is now generally given to changing the speed of the engine (Fig. 8).

Midwater trawling for shrimp

A number of years ago the catches diminished of the two-boat trawlers operating on the bottom in the East China Sea. The vessels then started fishing off the bottom and it was soon found that large and compact schools of shrimp were to be found in midwater. Since then a successful fishery with some 200 trawlers, based on these high-swimming schools, has developed, which uses specially adapted trawls and techniques.

This method requires not only clear and accurate detection of the shrimp schools under the vessel, but also constant and accurate information as to the position of

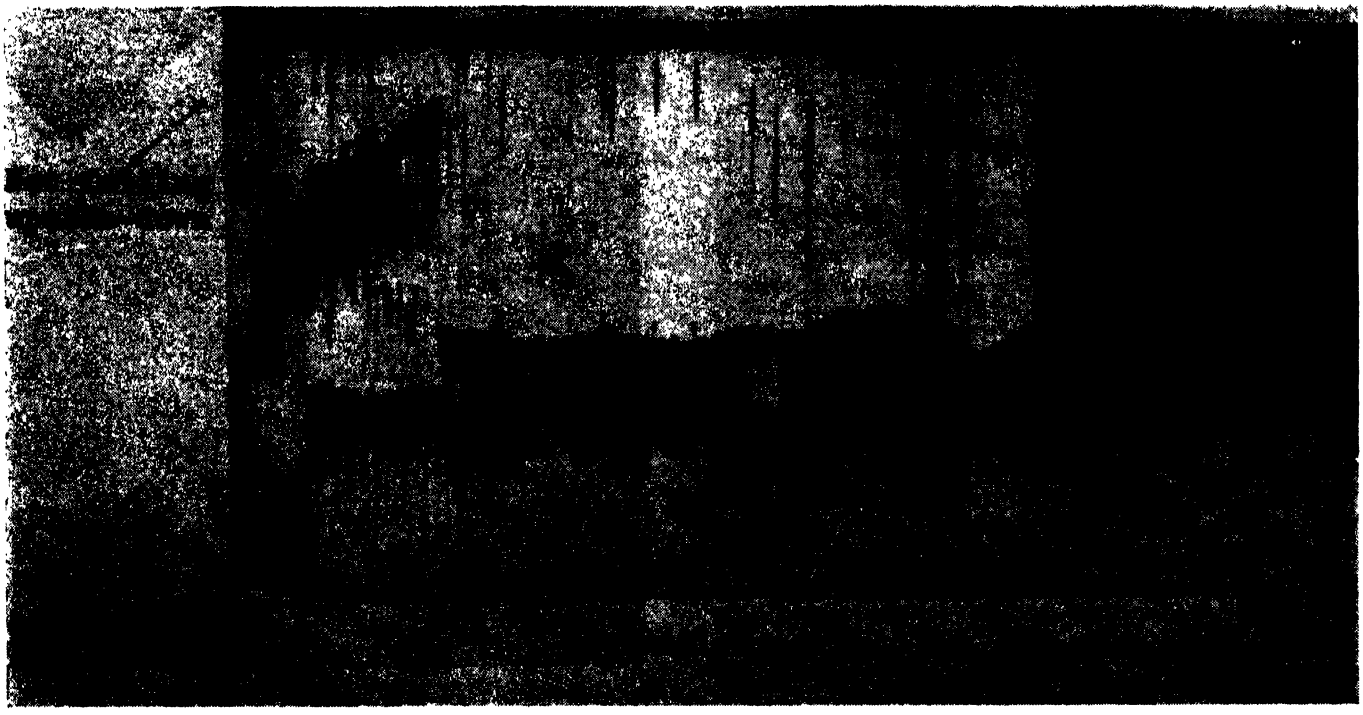

Fig 7. Example of a net entangled and subsequently adjusted while towing. Depth of water: 55 m.

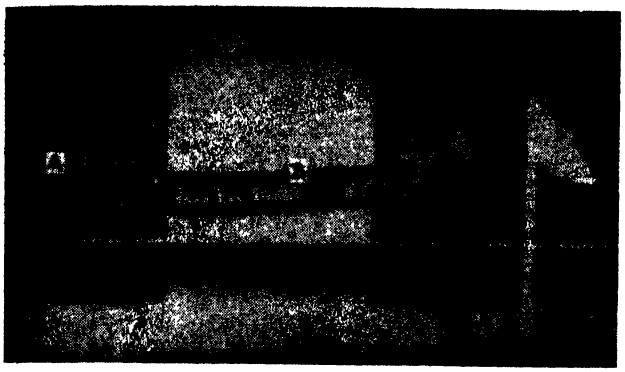

Fig 8. Example of aimed fishing for the prawn in midwater. A. School of the prawn before entering the net; B. School of the prawn after entering the net. Depth of water: 59 m.

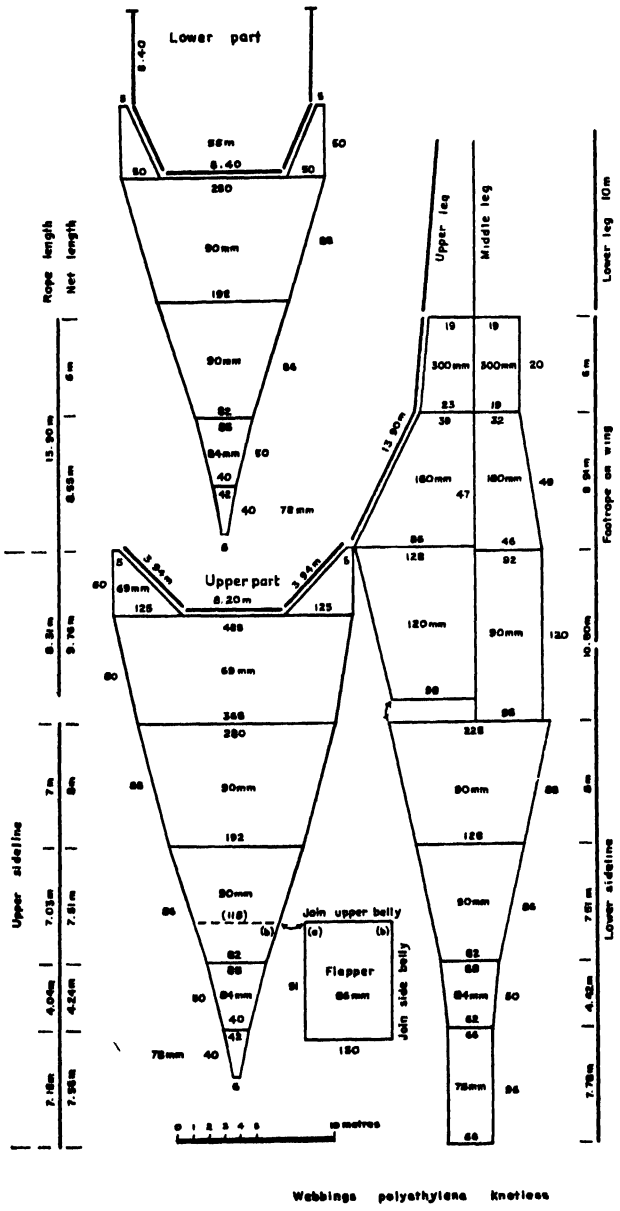

Fig 9. Shrimp midwater trawl.

the net so that it can be raised or lowered to intercept the schools recorded on the vessel's echo sounder. The above described Net-Vision technique, using 200 kc/s as

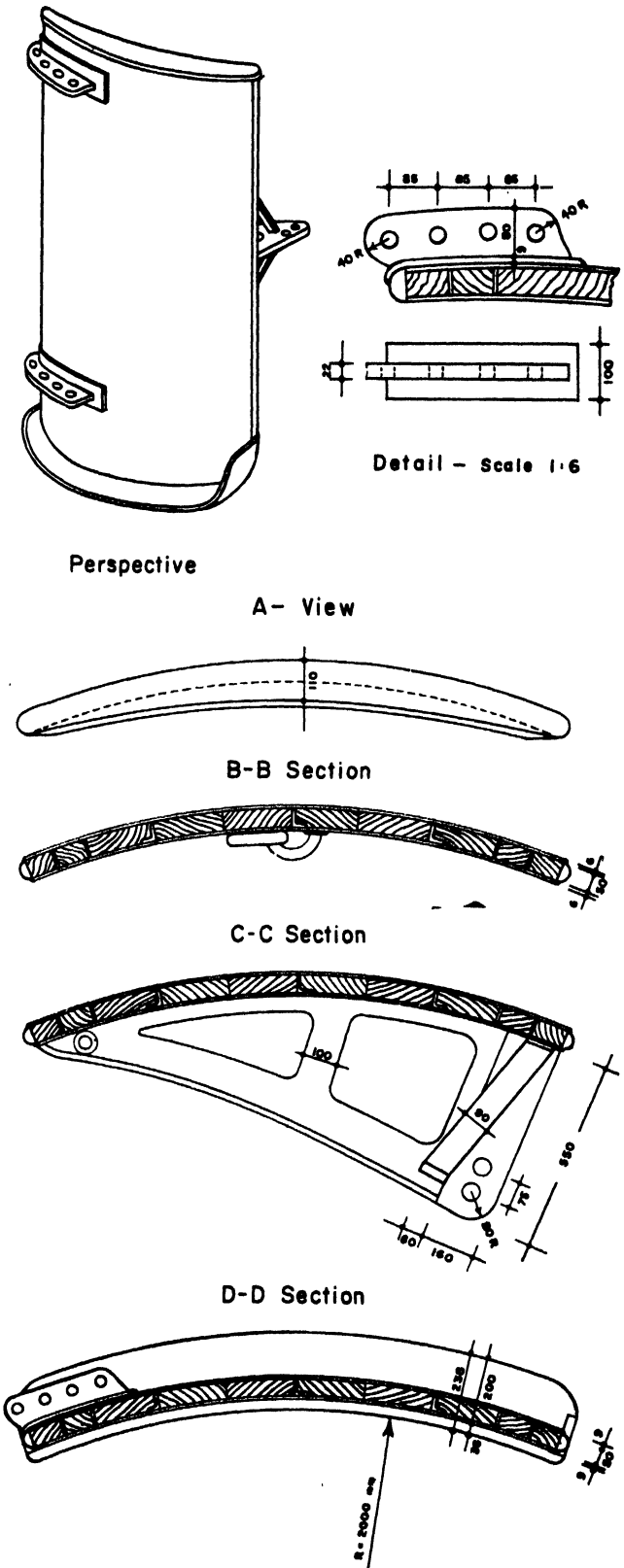

Fig. 10b. Perspective view and sections shown in 10a.

well as 28 or 50 kc/s is now in general use in this fishery.

The one-boat trawlers are commonly of about 44 m length with a displacement of 370 GT, powered by 700-800 hp engines. They normally carry a crew of 24 and are fitted with electric winches as well as all modern electronic appliances.

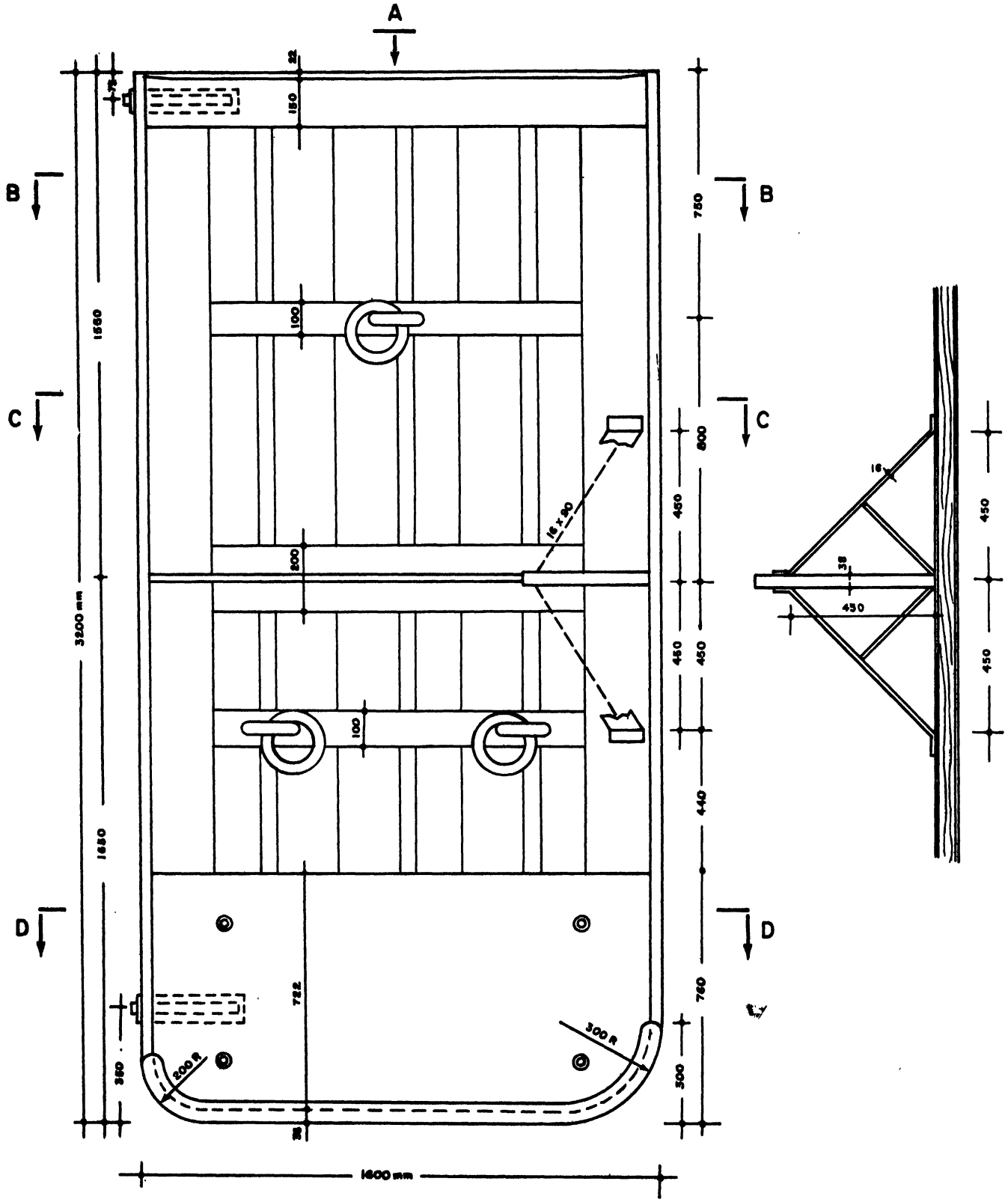

Fig 10a. High concave otter board for shrimp midwater trawl. Size 1,600 × 2,300 mm. Total weight 1,040 kg.

Two-boat trawlers are also used in this fishery; the vessels are smaller with engines of 350 hp each.

The gear

The trawlnets are of the 4-seam type and a common size is 44 m headline and a 55 m footrope. They are made entirely of black polyethylene knotless netting and rigged in such a way that in operation the main strain on the body is taken by the top sidelines which are appreciably shorter than the lower ones. The nets are made very long to improve water filtering to avoid the formation of adverse water pressure at the net mouth. Full details of construction are given in Fig. 9.

The nets are used with curved otter boards generally 3,200 mm high and 1,600 mm broad; they can be of steel-wood construction as shown in Fig. 10a and 10b as well as of all-steel construction.

The net is attached to the boards by three legs, of which the upper and lower legs are 60 m, while the middle leg is only 10 m long and attached to the upper leg.

The whole gear is rigged so that it can be operated on the bottom, just off the bottom, or in midwater, by altering the length of the upper and lower strops of the otter boards, and the length of the warps veered out.

Fig. 11 shows the rig of the trawls for a one-boat trawler. A similar net is used by two bull-trawlers of about 350 hp although of a somewhat bigger size with a headline of up to 80 m.

Conclusions

At the time of the first World Fishing Gear Congress in 1957, the studies and experiments on midwater trawling had advanced to where they showed high promise. All endeavours have been directed towards pelagic fish, and although many more experiments were carried out and more headway has been made since then, one-boat midwater trawling has, to the best of our knowledge, nowhere reached the commercial fishing stage on the same scale as in the fishery described above.

It may be that the particular fishery conditions in general and the reactions and compact school formation of the shrimp in the East China Sea are particularly suitable for this method of operation. On the other hand, these schools were only operated on with continued success after a proper type of net had been developed, giving a low resistance to the waterflow for very large opening dimensions, and a netzsonde system had been developed which allowed detection of the schools and at the same time accurate positioning of the net.

The next step is to adjust this gear to the catch of pelagic fish, and there seems to be no reason why it should not be successful there also.

The possibilities of application of the Net-Vision are not confined to commercial trawling alone and it is expected that this new device will also be useful for observing and measuring various phenomena, pertinent to fishing, in the course of fisheries and oceanographic investigations.

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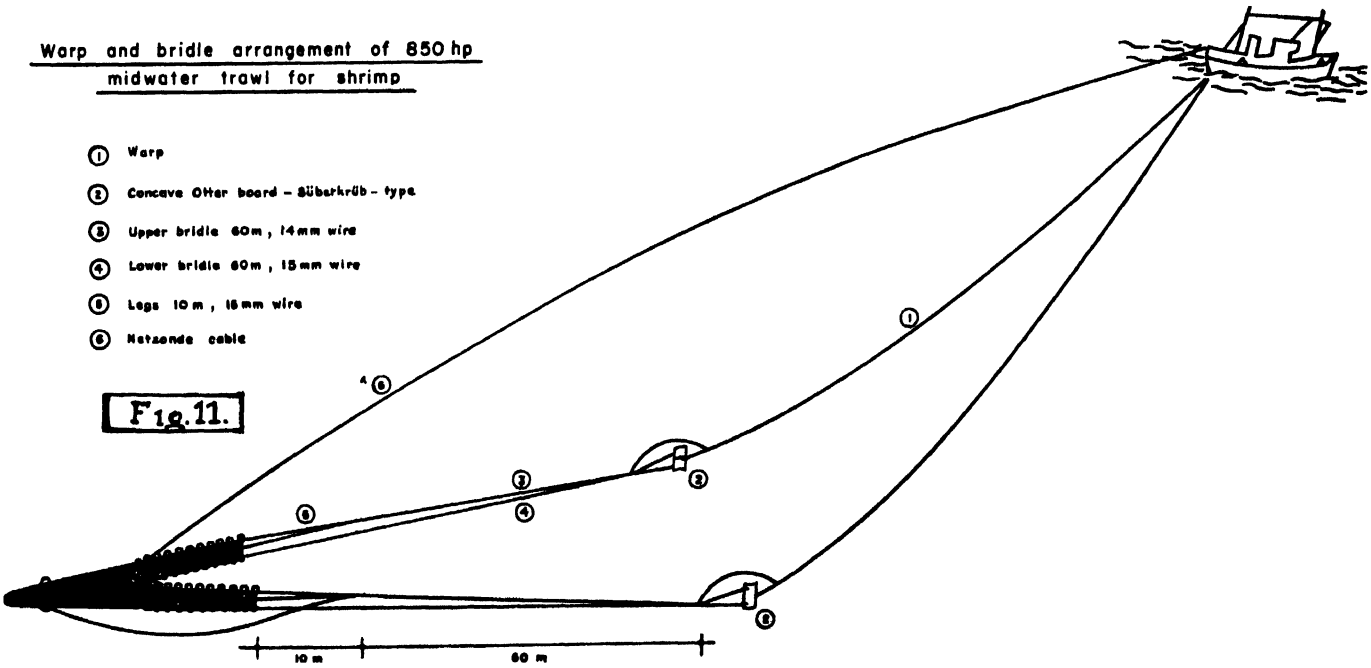


Fig. 11 Warp and bridle arrangement of shrimp midwater trawl.

Detecteur de Poisson "Explorator"

by
J. Fontaine

Compagnie Générale de Télégraphic Sans Fils (CSF)

Depuis une quinzaine d'années les navires de pêche modernes ont un équipement électronique que peuvent leur envier de nombreux navires de commerce. L'"Explorator" a été conçu pour assurer aux pêcheurs les moyens de détecter le gisement et la profondeur des bancs de poissons. Un tel instrument devait répondre aux exigences suivantes:

(a) Fréquence assez élevée pour obtenir un bon pouvoir de définition sans cependant donner lieu à une trop grande absorption qui nuirait à la portée.
(b) Faisceau très directif, donc angle au sommet très faible dans le plan vertical et une vitesse de balayage évitant des "trous" sur l'indicateur.
(c) Possibilité de varier la fréquence des impulsions selon la distance du banc de poissons.

Entre ces exigences plus ou moins contradictoires, il a fallu choisir des solutions de compromis qui ont amené à l'adoption des caractéristiques suivantes:

Fréquence, 61 KHz.
Ouverture de faisceau dans le plan vertical, 2°
dans le plan horizontal, 10°
Vitesse de balayage, 45° en 14 secondes.
Durée des impulsions: variable entre 1 et 30 millisecondes.

Le projecteur de l'"Explorator" monté dans un double fond est protégé par un carénage.

Les premiers appareils de série sont sortis à la fin du premier semestre 1962 et à ce jour, 10 "Explorators" fonctionnent, la plupart sur des chalutiers hauturiers. Les résultats obtenus ont été excellents et les patrons peuvent détecter le poisson près du fond à des profondeurs de 60 à 100 brasses avec un site de 20°.

L'étude souligne l'importance de l'expérience du patron dans l'emploi de ce type d'instrument. Comme exemple est cité le cas où un patron de pêche, pare une combinaison judicieuse de réglage, a obtenu des résultats excellents à une distance de 1,200 m.

Echo ranger for fish schools

Extract

For several years, commercial fishing vessels have been equipped with electronic gear at least as elaborate as that carried by ocean-going cargo vessels. The echo ranger "Explorator" was developed to provide fishermen with a means of ascertaining the depth of fish schools as well as the horizontal distance and their direction from the vessel. The depth of schools outside the ship's course can be read off directly on a special indicator.

The special requirements of such an instrument are:

(a) A high enough frequency to obtain clear indication with a relatively low absorption loss.
(b) The beam must have a very small vertical angle and a sweep of such a speed that the vessel's speed does not create voids on the indicator.
(c) The possibility of changing the impulse frequency according to the school's distance.

These requirements are contradictory and for the "Explorator" a final choice was made on the following specifications: frequency, 61 KHz, vertical beam angle 2°; horizontal angle 10°; sweep speed 45° in 14 seconds; impulse from 1-30 ms. The instrument incorporates a retractable transducer mounted in the ship's hull.

The first instruments were installed in the fall of 1962 and at the time of writing, 10 "Explorators" are in operation, mainly on ocean-going trawlers. The results obtained have been excellent in that the skippers currently obtain clear detection of fish near the bottom in depths of 60-100 fm at an angle of 20°. The paper further points out the importance of the skipper's experience in manipulating the instrument to obtain proper results from it. As an example, the case is cited where a skipper obtained excellent results at more than 1,200 m distance.

Ecotelemetros para la localizacion de cardúmenes

Extracto

Desde hace varios años los barcos de pesca están dotados de material electrónico tan completo como el que llevan los mercantes de gran altura. Se construyó el ecotelémetro "Explorator" para facilitar a los pescadores un medio de determinar la profundidad y distancia horizontal a que se encuentran los cardúmenes, así como la dirección en que se mueven con respecto al barco. La profundidad a que se hallan los cardúmenes que no están en línea con el rumbo del barco la da un indicador especial.

El aparato tiene que reunir las características especiales siguientes:

(a) Una frecuencia lo bastante alta para dar indicaciones claras con pérdidas por absorción relativamente bajas.
(b) El haz deberá tener un ángulo vertical muy pequeño y tal velocidad de desplazamiento horizontal que la propia del barco no cree vacíos en el indicador.
(c) Deberá ser posible cambiar la frecuencia de los impulsos según la distancia a que se encuentre el cardumen.

Estas necesidades son antagónicas y para el "Explorator" se hizo una selección final de las características siguientes: frecuencia, 61 KHz, ángulo vertical del haz, 2°; ángulo horizontal del haz, 10°; velocidad de desplazamiento horizontal, 45° en 14 segundos; impulso, de 1 a 30 ms. El aparato cuenta con un transductor rebatible montado en el casco del barco.

Los primeros aparatos se instalaron en el otoño de 1962 y en el momento de preparar esta comunicación, existen 10 "Explorator" instalados casi todos en arrastreros de altura. Los resultados conseguidos han sido excelentes y los patronos obtienen localizaciones claras de peces cerca del donfo en profundidades de 60 a 100 brazas y con un ángulo de 20°. El autor menciona que el patrón tiene que adquirir experiencia en el manejo del aparato para alcanzar buenos resultados y cita el caso de uno que los logró excelentes en la localización de un cardumen a más de 1,200 metros de distancia.

L'EXPLORATOR est le fruit d'une etroite collaboration entre des patrons de pêche français éprouvés et les ingénieurs de la C.S.F. (Compagnie Générale de Télégraphie Sans Fil). Toujours soucieux d'augmenter la rentabilité de leurs navires, les pêcheurs ont demandé un appareil de détection des bancs de poissons qui, à l'encontre des asdics de pêche dérivés des asdics militaires, permette de lire immédiatement sur la bande enregistreuse:

la profondeur du banc de poissons ou sa hauteur sur le fond.
la direction ou gisement du banc.

La distance qui n'intervient que si le capitaine décide de capturer le poisson détecté, peut être lue sur un indicateur spécial.

L'Explorator a été conçu pour satisfaire à ces exigences.

Caracteristiques techniques

L'Explorator est une application particulière de la technique bien connue des ultra-sons. Ses caractéristiques originales résident dans la manière dont les résul-

tats sont présentés pour satisfaire aux impératifs ci-dessus.

La représentation géographique "en coupe" de la zone explorée, analogue à celle des sondeurs enregistreurs verticaux classiques, exige en ce qui concerne la faisceau ultrasonore:

(a) Une fréquence assez élevée pour obtenir un bon pouvoir de définition sans cependant donner lieu à une trop grande absorption qui nuirait à la portée.
(b) Un faisceau très directif, donc angle au sommet très faible dans le plan vertical.
(c) Une vitesse de balayage telle que l'avance du navire entre deux passages du faisceau ne crée pas de "trous" dans la zone explorée.
(d) Une durée et une fréquence des impulsions variables selon la distance d'exploration choisie.

Entre ces exigences plus ou moins contradictoires, il a fallu choisir des solutions de compromis qui ont amené à l'adoption des chiffres suivants:

Fréquence: 61 KHz.
Ouverture du faisceau:
dans le plan vertical ±2°.
dans le plan horizontal ±10°.
Vitesse de balayage: ±45° en 14 secondes.
Durée des impulsions: variable à volonté entre 1 et 30 millisecondes.
Fréquence des impulsions: liée au site et comprise entre 0·5 et 16·6 Hz.

La réflexion des ultra-sons sur le fond et les bancs de poissons permet de mesurer la distance de ces obstacles au navire par mesure du temps séparant l'émission de l'impulsion de la réception de son écho. Pour obtenir la représentation "en coupe", il faut convertir cette donnée en profondeur en faisant intervenir les lignes trigonométriques du site et du gisement. Il faut, en outre, inclure dans l'appareil des dispositifs d'asservissement et de téléaffichage. Enfin, les variations du régime des cadences et des longueurs d'impulsions compliquent singulièrement la réalisation des circuits de déclenchement et de marquage; ici une solution ingénieuse (couverte par des brevets), basée sur les phénomènes d'induction, a été adoptée.

Tout ceci montre que, si le principe de l'Explorator reste simple, la réalisation mécanique et électronique se révèle d'autant plus complexe que l'on a voulu faire un appareil robuste et aisément exploitable.

Description sommaire

L'Explorator se compose essentiellement de trois unités:

(a) Le meuble passerelle (Fig. 1) comprenant les chassis.
—commande des butées de fin de course du projecteur.
—générateur de tops.
—asservissements.
—réception.
—premier étage de l'émetteur.

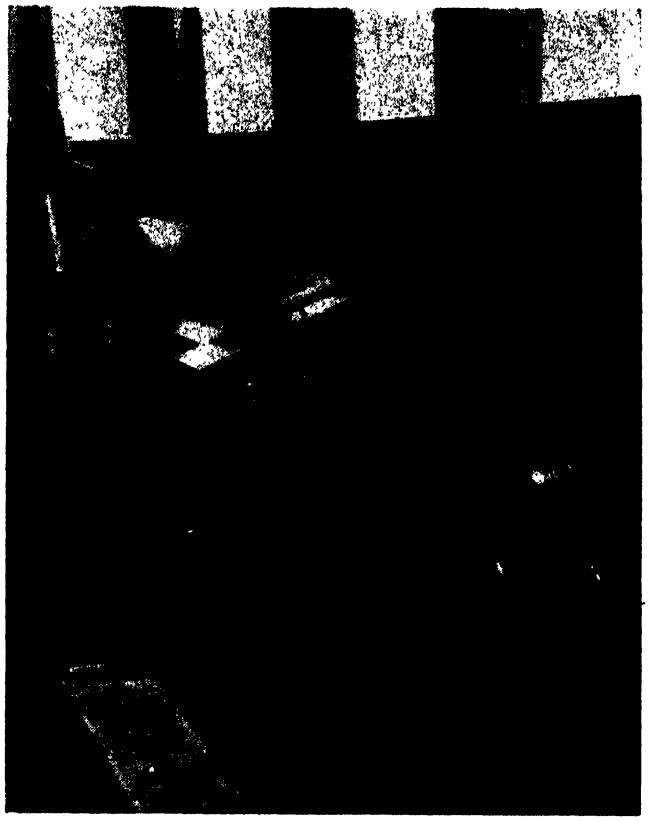


Fig. 1. Ensemble enregistreur-recepteur sur la passerelle d'un navire.

A sa partie supérieure, on trouve (Fig. 2) la table d'enregistrement sur laquelle se déroule le papier, l'indicateur site et l'indicateur gisement. Toutes les commandes sont rassemblées sur ce meuble.

(b) Le meuble émission-alimentation qui, ne com-

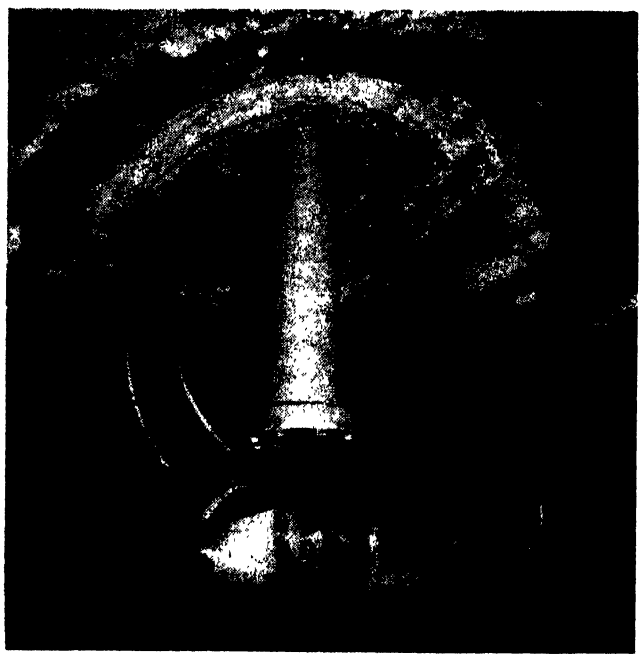
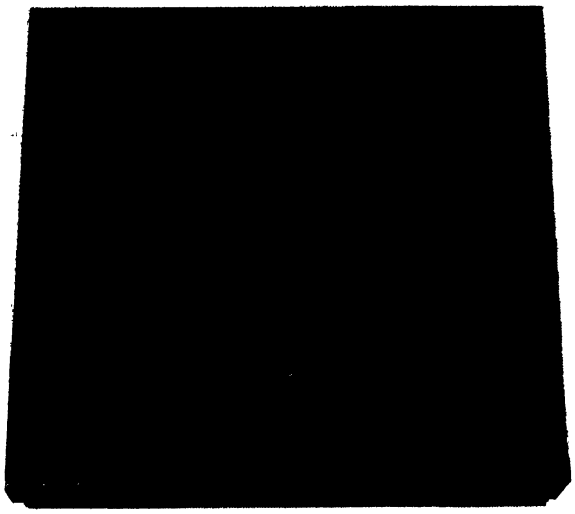
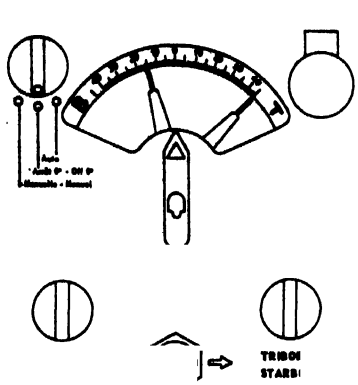


Fig. 3. Le projecteur en course d'installation sous la coque du navire.





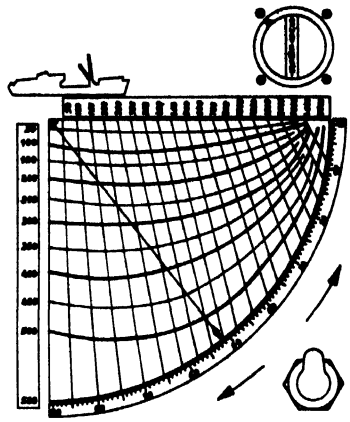


Fig. 2. Table d'enregistrement.

portant aucune commande, peut être placé n'importe où à bord et comprend:

—une alimentation régulée—150 V, +250 V.
—une alimentation régulée + 450 V.
—l'émission.
—les relais de commutation des moteurs du projecteur.
—les fusibles et relais de sécurité.
—les barrettes d'interconnexion des meubles.

(c) Le projecteur et son bloc mécanisme composé du "mécanisme de mouvement du projecteur" en site gisement. L'ensemble est monté dans un doublefond, le projecteur en saillie sous la coque et protégé par un carénage (Fig. 3 et 4).

Resultats d'exploitation

La maquette de l'Explorator mise en expérimentation à bord du chalutier *Saint-Louis*, a donné presqu'aussitôt des résultats assez remarquables pour que le patron, M. Delamer, et son armateur, M. Huret, demandent son maintien à bord jusqu'à la sortie des appareils de série.

Un deuxième prototype, mis en service à bord du navire de recherches fançais *Thalassa* en 1961, est considéré par le Commandant comme un des instruments de base pour les recherches de fonds de pêche et l'océanographie, en particulier pour la navigation sur des lignes isobathes.

Les premiers appareils de série ont commencé à sortir d'usine à la fin du premier semestre 1962. Au 1er mai 1963, les navires suivants étaient équipés:

France:

Thalassa—navire de recherches—Institut Scientifique des Pêches.

Saint-Louis, *Saint-Jean*, *Saint-Luc*—chalutiers—Pêcheries de la Morinie, Boulogne.

Jacques Coeur, *Jacques Cartier*—chalutiers—Pêche et Froid, Boulogne.

Zélande—chalutier de Grande Pêche—Pêcheries de Bordeaux-Bassens.

Fig. 4. Le projecteur installé, avec son carénage de protection.

Cabellou—thonnier coque bois de 120 tonneaux—M. Dhellemmes, Concarneau.

Royaume-Uni:

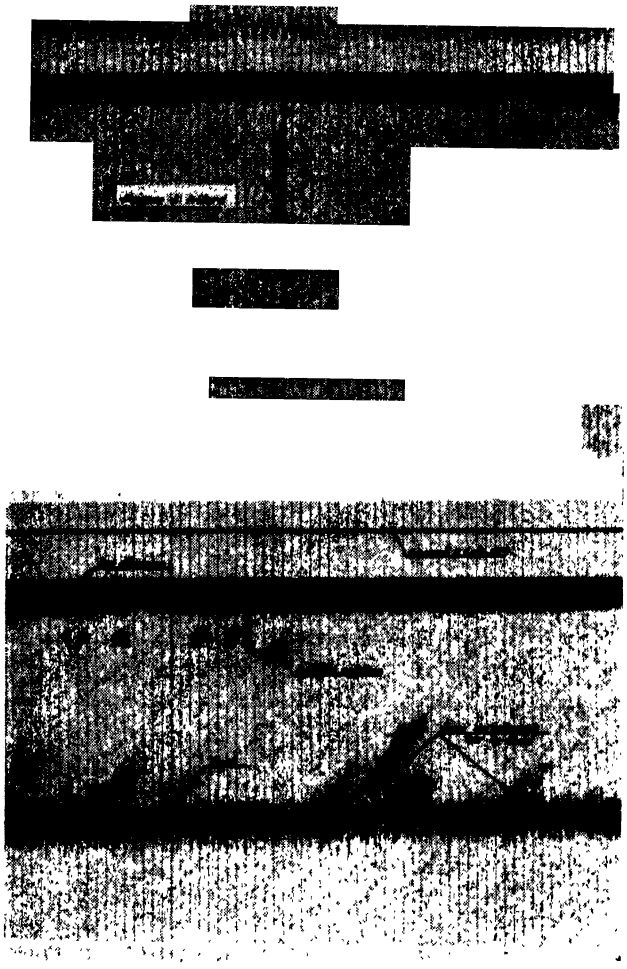
D. B. Finn—chalutier—St. Andrew's Steam Fishing Co. Ltd.

Norvege:

Longva—chalutier-usine—Longvadal, Aalesund.

Plusieurs autres navires français et étrangers doivent être prochainement équipés.

Il est difficile, pour plusieurs raisons, de donner dès



Figs. 5 and 6. Photos de bandes enregistrées à bord du chalutier Saint-Louis.

maintenant des résultats statistiques d'exploitation. Il conviendrait d'abord d'avoir une expérience de plusieurs années sur de nombreux navires. Ensuite, selon les ports, même à l'intérieur d'un pays donné, les espèces recherchées, donc les fonds fréquentés et les méthodes de pêche varient considérablement, ce qui compliquerait

Fig. 9. Photo de bande enrigistrée à bord du chalutier Saint-Louis.

le dépouillement des résultats. Enfin, s'il est relativement aisé de relever les quantités et prix des poissons débarqués, il est beaucoup plus délicat d'obtenir des patrons de pêche des informations sur leurs méthodes de pêche, leurs engins, les fonds qu'ils fréquentent, etc. A cet égard la pêche est un art; chaque artiste a ses secrets et une personnalité qu'il doit défendre, ce que l'on comprend aisément.

Monsieur Maurice Delamer, qui commande le chalutier *Saint-Louis*, a bien voulu nous faire un commentaire général basé sur deux années d'expériences et que nous résumons ci-dessous.

La mise en oeuvre de l'Explorator, pour aisée qu'elle soit, n'en demande pas moins un certain apprentissage pour acquérir le doigté nécessaire au rendement optimal de l'appareil. Cet apprentissage ne peut être le fait que du patron de pêche lui-même qui, lorsqu'il aura acquis l'expérience suffisante, sera peut-être amené à modifier ses méthodes en fonction des informations dispensées par l'Explorator.

Il est certain que le mode opératoire est notablement différent selon qu'il s'agit de pêche pélagique ou de pêche sur le fond.

Par exemple, en essayant un chalut pélagique, Monsieur Delamer a obtenu avec un site de 7°, des portées horizontales supérieures à 1,200 mètres donnant à l'écoute des échos caractéristiques.

Jusqu'à présent, l'Explorator a été surtout utilisé en chalutage sur le fond. On lui demande alors de déceler des concentrations de poissons (même assez faibles ou diffuses), se trouvant à une hauteur au-dessus du fond inférieure à celle de la corde de dos du chalut, c'est-à-dire trois ou quatre brasses, dans les limites de portée de l'appareil. Si la trace reconnue paraît intéressante, il faudra la suivre et manoeuvrer pour amener le chalut sur le poisson. Ceci nécessite de la part du patron une bonne connaissance des boutons de contrôle, de l'incidence des réglages sur la détection et de l'interprétation des enregistrements. On ne peut à priori, définir des valeurs moyennes des réglages convenant à tel poisson par tel fond. C'est une affaire d'éxpérience et de doigté du patron qui doit tenir compte des conditions atmosphériques, de la nature et de la profondeur du fond, des mouvements de plateforme du navire. De même, il faut savoir tenir compte des lobes secondaires inévitables à tout projecteur d'ultrasons.

Par exemple, le skipper B. Warham du *D. B. Finn*, en pêche sur les côtes norvégiennes en février 1963, a pu découvrir un large banc de poissons en se guidant sur de faibles détections et ramener plusieurs fois des prises de 150 paniers. Suivant les mouvements du banc, il a ramené au port, en 19 jours de voyage, 2,400 kits vendus plus de 12,000 livres sterling, soit une prise supérieure de 40 pour cent à celles des autres navires pêchant dans les mêmes eaux. En appliquant la même méthode (nouvelle pour lui), il a ramené à un récent voyage 2,300 kits et, le 8 mai, il a déchargé 23,930 stones pour £13,070 (*Yorkshire Post* du 9 mai).

Le skipper B. Wharam met au crédit de l'Explorator

Bio-Acoustical Detection of Fish Possibilities and Future Aspects

Abstract
The possibility of using acoustical indications for locating fish has only been investigated during recent years. The conductivity of sound in water is about 3,200 times higher than in air and sound waves propagate 4.5 times faster. Modern hydrophones connected to recorders are now used to study fish sounds. Listening-in is done from boats or from permanent stations ashore connected to outlying devices such as the Japanese "Sonobuoy". The paper then discusses the sounds produced by sea animals and their sound mechanisms, such as those made by the air bladder, stridulatory and swimming movements. The intensity of fish sounds can be correlated to the internal motivation state of the animals; in pre-spawning and spawning periods the animals produce much stronger sounds than at other periods. Experiments to date have obtained some results in attracting and repelling fish and investigations in this direction are continuing, although little is known as to the effective range of fish sound patterns. The main present objective of sea acoustical studies is to establish standard sea animal sounds, leading to full recognition of the species producing such sounds.

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Detection de poisson par des methodes bio-acoustiques possibilites et aspects futures

Resume
Ce n'est qu'au cours de ces dernières années que l'on a commencé à rechercher la possibilité d'utiliser des indications acoustiques pour la lacalisation de poissons. Les sons sont conduits dans l'eau à une vitesses 3.200 fois plus grande que dans l'air et les ondes soniques se propagent 4,5 fois plus vite. Des hydrophones modernes reliés à des indicateurs sont maintenant utilisés pour l'etude des sons de poissons. L'écoute a lieu sur des bateaux ou des stations a terre permanentes, reliés à des instruments ancrés

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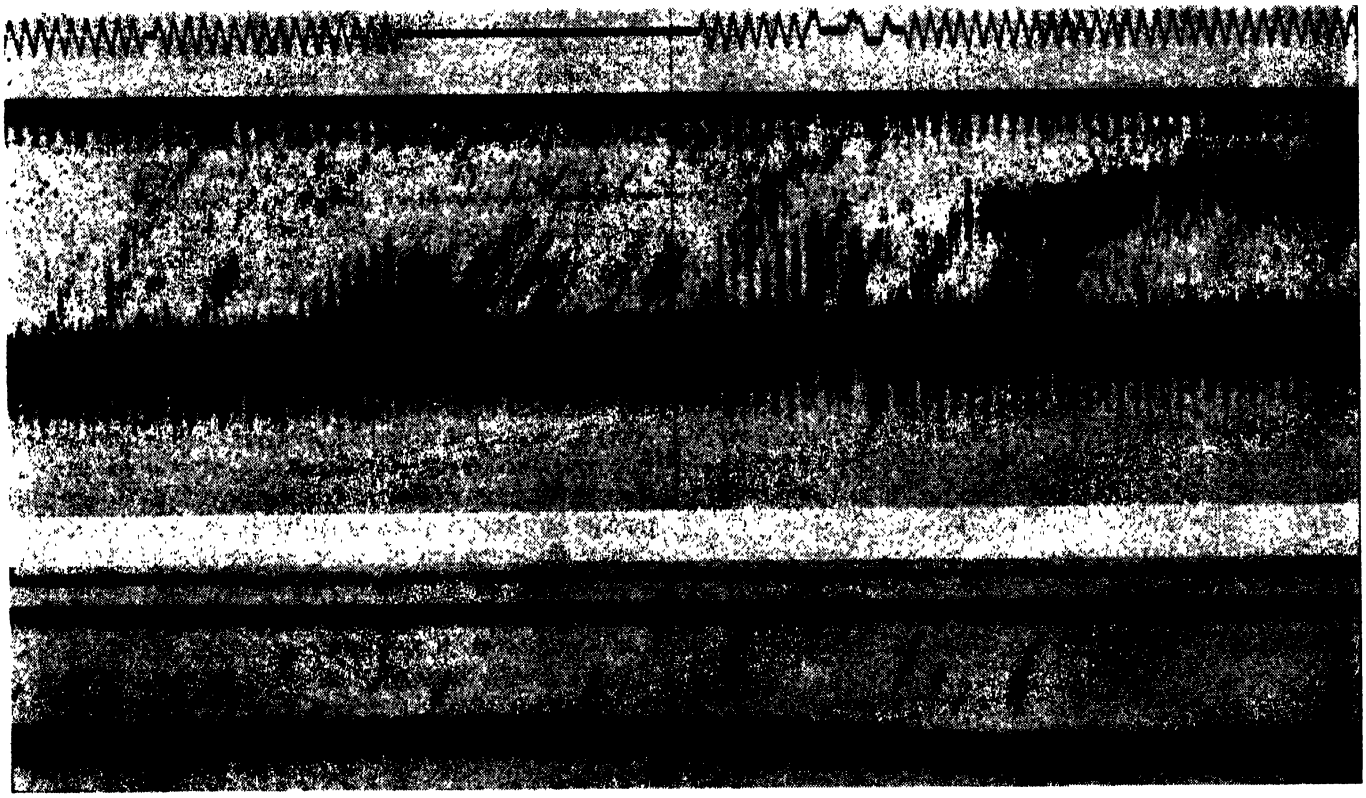

Figs. 7. and 8. Photos de bandes enrigistrées à bord du chalutier Saint-Louis.

9 pour cent du total de ses pêches.

Signalons enfin les excellents résultats obtenus par le chalutier *Saint-Jean* sur des bancs de colins noirs.

En ce qui concerne plus spécialement la pêche au thon, des expériences vont être faites sur le Cabellou, et peut-être d'autres navires, qui seront suivies avec intérêt par les milieux scientifiques et les armateurs.

Enfin, le Commandant Brenot, du navire de recherche *Thalassa* nous a signalé l'aide efficace que lui apporte l'Explorator en océanographie, en particulier dans la navigation sur une ligne isobathe, en l'informant à l'avance des variations du fond.

en mer tels que le Sonobuoy japanai. La communication traite des sons produits par les animaux de mer et de leurs mécanismes sonores tels que les vessies natatoires, ler mouvements de stridulation et de nage. L'intensité des sons de poissons peut avoir un rapport avec des causes internes: par exemple pendant la période précédant le frai et pendant le frai, les animaux produisent des sons beaucoup plus forts qu'à d'autres périodes. Jusqu'a présent les expériences ont obtenu un certain résultat concernant l'attraction et la répulsion des poissons et les observations dans ce sens continuent bien que très peut soient connues sur la portée effective des sons caracteristiques de poissons. A présent, l'objectif principal des études acoustiques en mer est d'etablir des sons standardises des animaux, dirigés sur la reconnaisance des espèces produisant ces sons.

Localizac ion bioacustica de los pecesposibilidades y aspector futuros

Extracto

La posibilidad de emplear indicaciones acústicas para localizar peces sólo se investiga desde hace pocos años. La conductibilidad del sonido en el agua es unas 3,200 veces mayor que en el aire y las ondas sonoras se propagan 4,5 veces más rápidamente. Se emplean actualmente hidrófonos modernos conectados a registradores para estudiar los sonidos que emiten los peces. Se escuchan desde embaraciones o desde estaciones fijas en tierra en comunicación con dispositivos distantes como la "sonobuoy" japonesa. El autor comenta los mecanismos que tienen los peces para emitir conidos, como los de la vejiga natatoria, chirridos y movimientos natatorios. La intensidad de los sonidos puede relacionarse con el estado interno que los motivan; antes y durante el desove los peces producen sonidos mucho más fuertes que en otros momentos. Experimentos realizados hasta la fecha han logrado ciertos resultados en la atracción y repulsión de los peces y continúan las investigaciones en esta dirección, aunque todavía se sabe muy poco del alcance efectivo de las modalidades de conidos de los peces. La finalidad principal de los actuales estudios acústicos marinos consiste en establecer patrones de conidos emitidos por animales marinos que culminen en el reconocimiento inequívoco de las especies que los producen.

TO localize fish or shrimp, etc., by listening to the sounds they make is an idea that has proved of interest to fisheries in recent years but the practical application of biological sound to fishing was started only recently.

There are two main methods for detecting underwater objects, echo-detection and acoustic-detection.

Acoustic detection is a passive method. Through watertight microphones (so-called hydrophones),underwater sound can be received and recorded. Different types of sound can be distinguished as:

(a) Ambient sea-noises:—caused by waves, current, and objects moving on the ground.
(b) Technical noises:—noises of ships, noise of the hearing device itself.
(c) Biological noise:—caused by marine animals, i.e. mammals, fish, shrimps, etc.

The noise-sources mentioned under (a) and (b) often limit reception of animal sound. Quantitative measurements of the level of the ambient sea-noise have shown that in every octave-range a sound pressure of 1 dyn/cm^2 is common and seldom exceeded. Biological noise level, however, under special circumstances, can reach 200-300 dyn/cm^2.

Sound signals spread in water about 4 to 5 times faster than in air. Much more important is the fact that the sound conductivity in water is about 3,200 times higher than in air.

Marine organisms have no genuine organs for sound production such as are found in terrestrial species. This is surprising in view of the reduced visual range under water and the poor optical properties of most marine animals.

During the last war, underwater microphones were developed which were specifically adapted to the reception of the pressure of sound-waves under water. The low voltage produced by the hydrophones is amplified by a preamplifier, and then recorded by a tape recorder. Preamplifier and tape recorder are self-contained so that they can be used anywhere.

Recording of underwater noise

Recent research shows that the continental shelfs are much more noisy than the open sea and so are better suited for investigations.

Reception of animal underwater sound is limited by the level of interfering noise. To avoid such interference the author has found an outboard-motor equipped rubber raft excellent for his purpose. The additional use of a transportable echo sounder made it possible to find fish concentrations and to lower the hydrophone to the proper level. The main factors which may still interfere with such investigations are sea and weather conditions and the sound level of concentrations of fishing vessels which are often found near the fish schools to be studied.

Listening from boats or vessels is naturally limited in time. Therefore permanent stations are preferably established ashore. They are connected by cables or wireless communication ("Sonobuoy") with one or several hydrophones which may be installed in free water or on the bottom. Their location requires careful selection.

In some instances, such listening stations have already found a certain commercial application. For instance, in the Japanese set net fishery, "Sonobuoys" which have a wireless transmission range of up to about 10 km, are placed in the anti-chamber of the trap. Since there is a close relationship between the intensity of biological noise and the amount of catch in the trap, it is possible to estimate the number of impounded fish[14].

According to Steinberg *et al*[24], 25 different categories of sounds were recorded over several months and it can be assumed that by permanent listening over long periods better results can be obtained.

A basic difficulty is that most of the underwater noise makers are invisible. The possibilities of using underwater-television or divers are limited. Monitoring fish in aquaria, therefore, is a useful method for establishing definite relations between noise and noisemaker, but noise-making fish have been found to behave in quite different ways when confined in aquaria for instance:

(a) Completely silent: *Opsanus* spec., *Aplodinotus* (freshwater drummer).
(b) Sounding with less spirit and vehemence: croakers.
(c) Sounding when seeing another individual of the same species: gurnard (*Trigla gurnardus*).
(d) Sounding after electrical stimulation: eel (*Anguilla vulg.*).

(e) Sounding when sounds of the same species are played back into the aquarium: *Prionotus, Trigla.*

Sound producing marine animals definitely established are:—

(a) Shells:—Some shells produce noise by clapping their shell-parts rapidly together or by pushing against each other in great colonies. The respiratory murmur of these animals lies in the ultra-sound region.

(b) Crustaceans:—shrimps and larger crustacean species make noise by moving their antennae, claws, etc. These sounds resemble the fire of burning twigs. Noise of this type can be heard very often in all parts of the oceans and even in small ponds as a steady background noise which often interferes with underwater listening.

(c) Squid:—the jet principle of their movements results in a typical noise. Furthermore these animals are able to produce an additional high pitched whistling sound by pressing out the water with violent force when attacked by predators.

(d) Fish:—approximately 400 fish species were acoustically monitored to find out the potential soundmakers. Fish sounds represent the main part of underwater animal soniferous activity.

(e) Marine mammals:—whales and dolphins have a very extensive catalogue of sounds. Until recently, it was not possible to find out the biological significance of all these different noises. Some are obviously used for echo-location in the water.

Sound-mechanisms in fish

Without a single exception, fish have neither lungs nor an air-reservoir in connection with the respiratory apparatus. The sounds created by fish, therefore, cannot be called "voices." Fish produce sounds by a variety of different physical mechanisms, and the following, sound-producing mechanisms can be distinguished: (a) Air bladder-mechanisms, (b) Stridulatory-mechanisms, (c) Swimming sounds: by either single fish or fish schools.

Air bladder mechanisms—Well developed sound-mechanisms are found in those species which are able to set the air content of the air bladder into vibration by rhythmic contractions of the lateral body muscles or by the activity of special drum-muscles. In the latter case the innervation is provided by a ventral rampus of the II. spine-nerve. These contractions can be performed at will by the animals. These air bladder mechanisms are operated by an astonishing variety of constructions. Sounds so created are in all cases low pitched grunts with the greatest pressure values in the region of 50 to 400 cycles per sec (cps).

Stridulatory-mechanisms—These are anatomically much simpler than air bladder mechanisms. Analogous to insects, sound is produced by rubbing certain parts of the skeleton against each other. Generally these moving parts are teeth (eating sounds), fin-parts, etc. Sound so produced is much higher pitched than air bladder sound and lies generally between 200 and 5,500 cps.

With many particularly noisy fish species, sound-production is more complicated because several mechanisms are engaged simultaneously, such as the combination of teeth-grinding with air bladder resonance effecting an increase of sound level.

Swimming sound—the swimming noise of single fish normally does not exceed the ubiquitous background noise of the sea. A slight rushing can be recognized if the fish moves in an aquarium very close to the hydrophone. When it darts or touches the surface of the water with the tail-fin, a drum-like noise will be caused. Sounds of this kind of origin are called "mechanical or hydrodynamical." Moulton (1960) proposes the expression "swimming sound" as more purposeful regardless of whether they are created by the movement of bones, by contractions of the swimming muscles or of hydrodynamic origin.

Fish schools at rest create no audible sound but if the school moves or veers a considerable noise results—the more the deviation or velocity, the greater the noise level. Swimming sounds of moving fish schools are not permanent. This demonstrates that neither contractions of muscles nor hydrodynamical effects can be responsible for these swimming sounds. Specific differences of noise exist according to the schooling species, and the size of the school. Swimming sounds of larger fish are lower pitched than those of smaller fish.

Veering of fish schools can create additional acoustical phenomena. The origin of this sound-type is not quite clear. Such veering sounds of herring schools resemble a high whistling sound reaching 6 to 7 kcps. (Murray[20], Freytag[10]). Harris[13] heard a similar noise when schools of menhaden crossed under vessels. They described that noise as similar to the high pitched squeaking of field-mice.

Listening to schools of mackerel and tuna have given no satisfactory results. Investigations in aquaria by establishing schools of more than 1,000 individuals of genus *Anchoviella* and *Atherina* also gave no useful sound production. In all cases only a slight rushing was to be heard[19]. It is possible, however, that some of the sound accompanying swimming activity lies in a higher frequency range for which normal underwater hearing devices are not receptive.

Future aspects: Current status of bio-acoustical methods

Through motor driven vessels in European fisheries knowledge about hydrodynamical and biological noises in the sea decreased steadily. Much more experience on this subject can be found with fishermen off the coasts of Africa, Asia and the Pacific who fish with small, unmechanized and therefore "noiseless" boats. They succeed in locating and estimating the magnitude of fish schools by eavesdropping at the hull or by using special hearing instruments like paddles, etc., which are dipped into the water. The success of these techniques depends mainly on the personal experience of the listening fishermen and on the quality of the hearing instruments.

It is not yet possible to predict which bio-acoustical methods may be used in future in practical fishing, but suggestions can be made.

Diurnal rhythms of sound production are well known from mammals, birds and amphibious animals. They are also known from many marine animals. The sound activity of certain shrimps, for instance, shows a two-fold increase at sunset with highest activity just before sunrise and after darkness falls. Sea Catfish (*Galeichthys* sp) and the fish of the genus *Opsanus* produce their numerous sounds only at night. The freshwater drum (Aplodinotus) starts to sound around 10.00 h, reaches a peak in the afternoon and stops at sunset[23].

Only theories apply to the frequency with which fish can produce sound in active periods. Since fish may use one and the same sound type under several different biological conditions (spawning, attack, fright) it can be concluded that the sound mechanism is not closely coupled with one definite instinctive behaviour. It is rather assumed that sound mechanisms in fish are of a reflex like nature so that a longer lasting functioning of a soniferous activity can be expected. With gurnard the author recorded 4,600 drumming sounds within six hours.

The sound intensity is correlated to the internal motivation state of the animals. During courtship and the following spawning period the same sounds are produced but with more vehemence in comparison with other seasons. Especially when fish concentrate for spawning, the single sounds as well as the resulting chorus reach a considerable amount of sound pressure by "social infection." The drumming concerts of the sciaenid fish are a typical example. These temporary concentrations of fish during spawning provide favourable conditions for typical fishing seasons during which in some cases, passive listening is being used for fish detection[8].

Passive listening

Much more attention should be paid to performances of the fish brain which are connected with experience and learning. There are well-known cases of self-training, e.g. in connection with the breeding territory, or the reaction of sharks to moving ships, etc. It is possible that technical noises connected with fishing such as echo sounding, noise of engines and propellers could be associated with the following disturbances by the fishing gear, so that fishes would start to flee from the vessel long before the fishing gear and its noise becomes recognizable.

Investigations regarding the noise level of fishing must try to distinguish between the ship's noise and the noise created by the gear[22]. Some results in this field had been obtained by a working group in Bergen, Norway, in connection with the development work on one-boat mid-water trawl[12].

The use of bandpass filters is not possible because the frequency range of these technical ship noises (10 to 5,000 cps) covers the whole range of biological sound. The sound pressure of a trawler's noise which depends to some extent on the motor revolution, is in a distance of 200 m, still more than 1μ bar.

Attracting and repelling

The counteracting effects of influencing fish by sound are treated together because it can only rarely be decided whether an effect is attracting or repelling and which or both prevails.

Some knowledge is available on influencing fish by playing back their own species' specific sounds[19]. The author's own investigations with gurnards showed that it is possible to attract the fish to the noise-source (loudspeaker). But the "interest" decreased and they soon turned away because of the missing optical stimuli of the "expected" species partner.

Compared with this possibility of influencing fish with their own species specific sound, influences based on the preyfish predator relation seem to be more promising. Schooling fish are always frightened by the feeding noise of their predators[19], while predatory fish are attracted by the swimming noise of the schooling preyfish. If those predator species are subjected to their own feeding sounds, they show catching reactions and increase their swimming activity in search of prey.

Little is known to date on the range in which reactions to acoustical patterns can occur. It is known, however, that actual biological sounds and artificial sound products can influence animal behaviour. This is, however, true only for "noise" and single distinct tones produced by frequency generators have been found inefficient.

The application of sound attraction or repelling may be valuable in connection with traps, seines, gillnets, etc., or in areas where a rough seabed hampers fishing. Fishing in connection with noise for attracting or repelling is mentioned in literature in several cases[5], [15]. One type of German fishery in the Baltic ("Klapperfischerei") is performed by using striking noises to scare the fishes into the nets under the ice.

Outlook

Animal underwater sounds have been a special subject of research for over 20 years. It is well known, that biological noise can be expected everywhere in all oceans. The continental shelf zones are much more noisy than the open oceans. Many countries have started to study their shelf areas in regard to biological sound production, with a view to utilization for fishing. The "fishermen of tomorrow" will have to rely much more on electro-acoustical devices than on his eyes or ears for measuring the depth and other distances, estimating the amount of catch and for transmission of all sorts of values and observations by underwater sound.

All these techniques require a good knowledge of all sorts of underwater sound signals and, in view of the abundance of animal underwater sound production, also the capability to recognise and distinguish between the different sounds and the background noise level. As the sound producers are usually invisible and often far away from the hydrophone, they have to be identified also by laboratory tests in aquaria. In the Narragansett Marine laboratory, Rhode Island, all bioacoustical data from field and laboratory tests are collected in a sound

Study of Acoustical Characteristics of Fish

Abstract
For designing hydro-acoustical instruments useful for commercial fisheries, as well as for surveys aimed at assessing fish populations, more information is required regarding the attenuation of the strength of signals between emission and reception of the echo. The Research Institute of Marine Fisheries and Oceanography of the USSR has conducted a study of the acoustic characteristics of fish and fish schools, and this paper gives in some detail the method of approach to the problem, the mathematical treatment and some of the results obtained. It is stated that while the individual echo signals of a school of fish are strengthened by reflections from the fish, the total echo strength is nevertheless attenuated by absorption of the ultrasonic energy by the fish bodies. The formulae expressing the attenuation of the echo signals are provided. The reflection capacity differs of course between fishes and depends not only on the form of the fish body but also on the presence, or absence, of a swim bladder. The author found that the coefficient of reflection depends on the frequency of the ultrasonic sound. The investigations showed that the intensity of the echo signal is proportional to the pulse length so that echo signals returned by fish schools were not only increased in amplitude but also prolonged. This results in records of fish schools being over-estimated in the vertical direction and may even some time show an extension to beyond the bottom line. A diagram based on acoustical measurement during the investigations shows that the coefficient of attenuation of the echo signal increases with an increasing concentration of fish. A considerable part of the energy of a sonic wave reaching the fish school is scattered so that only a small part of the energy transmitted returns to the receiver. This loss of propagation increases with the frequency.

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Etude des caracteristiques acoustiques des poissons
Resume
Pour dessiner des instruments hydro-acoustiques pour la pêche commerciale, il est nécessaire d'avoir davantage d'informations concernant l'affaiblissement de la force des signaux entre l'émission et la réception des échos. L'Institut de recherche des pêches maritimes et de l'Océanographie de l'URSS a conduit une étude des caractéristiques acoustiques des poissons et des bancs de poissons et la communication donne quelques détails de la méthode employée, la solution mathématique et quelques uns des résultats obtenus. Il y est dit que, bien que les signaux individuels d'un banc de poissons soient amplifiés par la réflexion venant du poisson,

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archive[7]. Based on this material it will one day be possible to make predictions regarding the general sound conditions in the oceans.

Progress in this field of bioacoustics could be strengthened if scientists could be supported by observations of sailors on an international scale. Acoustical data from ships should be supplemented by log-books, notes, and echograms.

One final aim is to establish standard animal sound-types, e.g. for shrimps, fish, etc., which are to be subdivided according to frequencies and the different sound mechanism. While today the special knowledge needed for this subject depends mainly on the personal experience of specialists, it will then be possible to spread this knowledge to every interested fisherman.

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la force totale de l'écho est néanmoins affaible par suite de l'absorption de l'énergie ultra-sonique par le corps des poissons. Des formules exprimant cet affaiblissement sont fournies. La capacité de réflexion diffère entre les poissons et dépend de la forme du corps mais aussi de la présence ou de l'absence de vessies natatoires. L'auteur a trouvé que le coefficient de réflexion dépend de la fréquence du son ultra-sonique. Les expériences ont montré que l'intensité de l'écho était proportionnelle à la longueur de pulsation de sorte que les échos renvoyés du banc de poissons étaient non seulement amplifiés mais aussi prolongés. De ce fait les enregistrements de bancs de poissons sont surestimés dans la direction verticale et peuvent parfois même s'étendre jusqu'au-delà du fond. Un diagramme basé sur les mesures acoustiques prises pendant les investigations montre que le coefficient d'affaiblissements des échos augmente avec l'accroiseement de concentration du poisson. Une quantité considérable d'énergie d'une onde sonique aboutissant au banc de poissons est diffusée de telle manière qu'une petite quantité seulement de l'énergie retourne au récepteur. Cette perte de propagation grandit avec la fréquence.

Estudio de las caracteristicas acusticas de los peces

Extracto

Para proyectar instrumentos hidroacústicos de utilidad en la pesca industrial y en los reconocimientos destinados a evaluar las poblaciones ícticas, se necesita más información respecto a la atenuación de la fuerza de las señales desde la emisión hasta la recepción del eco. El Instituto de Investigaciones de Pesca Marítima y Oceanografía de la URSS ha estudiado las características acústicas de peces individuales y de cardúmenes y en esta ponencia se dan detalles de la manera de enfocar el problema, su tratamiento matemático y algunos resultados obtenidos. Se afirma que aunque los ecos individuales de un cardumen se refuerzan por reflexiones de los peces, la ruerza total del eco se atenúa por absorción de la energía ultrasonora por los cuerpos de los peces. Se dan fórmulas que expresan la atenuación de los ecos. La capacidad de reflexión varía entre peces y depende no sólo de la forma del cuerpo sino también de la presencia o falta de una vejiga natatoria. El autor observó que el coeficiente de reflexión depende de la frecuencia del ultrasonido. Las investigaciones demostraron que la intensidad del eco es proporcional a la longitud del impulso, de modo que los ecos obtenidos de cardúmenes no sólo aumentaron en amplitud sino que también se prolongaron. Esto da por resultado una sobrestimación de los registros de cardúmenes en dirección vertical que en ocasiones pueden indicar una extensión más allá de la línea del fondo. Un esquema basado en medidas acústicas realizadas durante las investigaciones demuestra que el coeficiente de atenuación de la señal del eco se incrementa con la concentración de peces. Una gran parte de la energía de una onda sonora que llega a un cardumen se dispersa de modo que sólo una pequeña parte de la energía transmitida regresa al receptor. Esta pérdida de propagación aumenta con la frecuencia.

THE study of the acoustic characteristics of fish is of great importance for designing hydroacoustic instruments used in fishing as well as for developing methods of estimating the fish abundance, based on data obtained with such instruments.

It is known that the radius of the equivalent sphere of a flat-shaped fish school depends on the number of fish in the school:

$$R_e = R_1 \sqrt{n}$$

where

R_e —radius of the equivalent sphere of school

n —number of fish in the school

R_1 —coefficient in function of frequency, size and species of fish. Numerically the coefficient is equal to the radius of the equivalent sphere of a single fish at a given frequency.

In actually existing volumetric schools the echo signal is built up by reflections created by all the fishes receiving not only the direct pulse emitted by the transducer, but also the additional ultrasonic energy reflected by the fish within the scattering space element. This useful reverberation of a volumetric fish school accounts for the increased strength of the produced signal as compared with signals returned by plane schools. A quantitative estimate of the effect of multiple reflection may be obtained from Fig 1, the dotted curve given for a

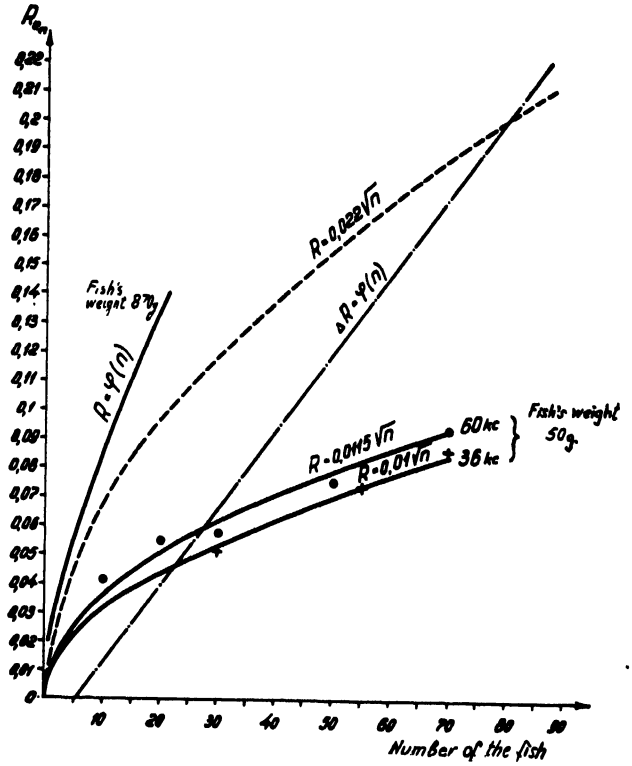

Fig 1. Relation of radius of equivalent sphere to number of fish in a school.

school of large horse mackerel is derived from the equation given above. The radius of the equivalent sphere of a single horse mackerel 46 cm long is equal to 0.022 m. On the same figure is given a curve:

$\Delta R = \varphi(n)$ where

$\Delta R = R_e$ (volumetric school) $- R_e$ (flat school)

It shows that ΔR is linear and dependent on the number of fish above a certain minimum, guaranteeing a multiplicity of reflections. In our experiments this minimum was provided by four fishes. The increase of the radius of the equivalent sphere of a fish school accounted for by multiple reflection is obtained from the equation:

$\Delta R = b(n-4)$ where

n —number of fish

b —experimentally determined coefficient characterising the ultrasound scattered by a single fish at a given frequency (in our case a horse mackerel 46 cm long, at a frequency of 50 kc/sec $b=0.0025$).

In actually existing fish schools, apart from the increase in signal strength induced by repeated reflections, there is also a partial decrease in strength, owing to the absorption of ultrasonic energy by the fish bodies.

The attenuation of ultrasound was measured for different numbers of fish at a frequency of 50 kc/sec. It may be assumed with a reasonable degree of accuracy that $\triangle^{\delta}_{fish}=3$ db/km for horse mackerel of 23 cm and $\triangle^{\delta}_{fish}=6$ db/km for horse mackerel of 46 cm.

Hence we may determine how many times the intensity of sound will be changed when passing through a fish school extending over 1 km.

$$\triangle^{\delta}_{fish}= 20 \lg\frac{I}{I_0}$$

$$\lg \frac{I}{I_0}=\frac{\triangle^{\delta}_{fish}}{20}=\frac{6}{20}=0.3$$

consequently

$$\frac{I}{I_0}=2$$

In our case the pulse length (1ms) corresponded to a thickness of the scattering space element of 0.75 m; the coefficient characterising the changes of intensity of the ultrasound caused by absorption by the bodies of fish is then:

$$y=\frac{I}{I^{\circ}}=\frac{\frac{c\tau}{2}}{1000}=2\frac{0.75}{1000}=0.0015$$

Therefore, taking into account the useful reverberation in the school and the attenuation of ultrasound within it, the equation for calculating the radius of the equivalent sphere of a school of horse mackerel of 46 cm, at a frequency of 50 kc/sec becomes:

$$R_e=0.022\sqrt{n}+\frac{0.0025\,n-0.01}{I+0.0015\,n}$$

This equation gives sufficiently exact results provided the fish in the school are distributed so as not to screen one another. In the contrary case the coefficient will be considerably lower. Generally this equation can be represented in the following form:

$$R_e=R_1\sqrt{n}+\frac{b\,(n-4)}{I+yn}$$

The diagram of relation of the equivalent sphere to the length and weight of fish is based on the results of acoustical measurements carried out over three years

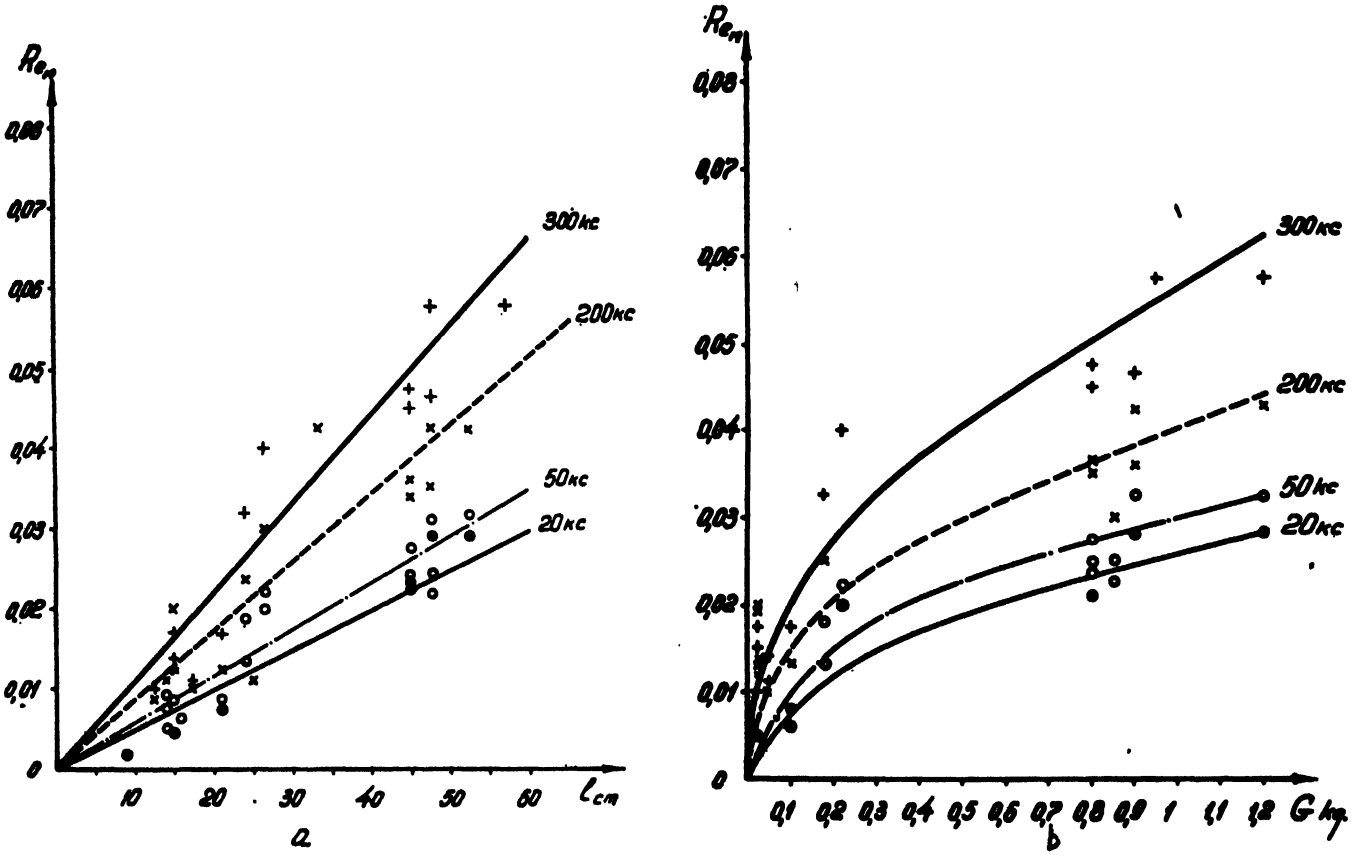

Fig 2. Relation of radius of equivalent sphere to (a) length and (b) weight of fish.

(Fig 2a). It shows that the radius of the equivalent sphere is considered to be directly proportional to the length of the fish. The angle of slope of the direct line varies with varying frequencies. If R_e is expressed in meters and the length of fish in meters too, the angular coefficient for different frequencies will have the values shown in Table I:

Table I

Frequency kc/sec	20	50	200	300
$\frac{R_e}{l}$	18	15	11	8.2
$R_e = \varphi(l)$	18l	15l	11l	8.2l

Fig 2b shows that the relation of the radius of the equivalent sphere to the weight of fish is expressed by the parabola:

$$R_e = k_f\sqrt{G}$$

where

G—weight of fish

k_f—proportion coefficient related to frequency

The coefficient k_f has a certain definite value at each frequency (Table II):

Table II

Frequency	k_f	$R_e / = /k_f / \sqrt{G}$
20	0.84	0.84 G
50	1.04	1.04 G
200	1.38	1.38 G
300	1.85	1.85 G

The reflecting ability of different pelagic fishes can be obtained from the diagrams in Fig 2, if, as a first approximation, the shape of their bodies is assumed to be similar to that of the horse mackerel. Using the data given above, the author was able to calculate the radius of the equivalent sphere of a whale on the assumption that wave resistance of the whale is near to that of fish. It was assumed too that the body of the whale has the same form as a pelagic fish. Subsequently the radius of the equivalent sphere of the sperm-whale was determined by measurement and it was found that the difference between the computed and measured values did not exceed 10 per cent. This means that the diagrams in Fig 2a can be used for theoretical calculation of the reflective ability of fish of any size from sprat to whale size, i.e. from 10 cm to 10 m, with an accuracy sufficient for practical purposes.

The reflective ability of fish depends also on the form of the body and presence or absence of a swimbladder. If the cross-section of the fish is elliptical with the major axis directed vertically, a smaller surface is involved in the reflection of ultrasound than in flat fishes. Also fish without swimbladders may sometimes give stronger echo signals than fish of similar weight with swimbladders. Using the diagrams in Fig 2a and 2b we can determine the echo signals given by fish without swimbladders with a body form like that of the horse mackerel. In this case one must make corrections for the ratios of coefficients of reflection of fish with and without swimbladders:

$$R_{e\ \text{without swimbladder}} = R_{e\ \text{swimbladder}} \frac{\beta_{w/s}}{\beta_s}$$

According to results obtained during our experiments, the value $\frac{\beta_{w/s}}{\beta_s}$ depends on the frequency (Table III):

Table III

Frequency kc/sec	30	50	100	200	300
$\frac{\beta_{w/s}}{\beta_s}$	0.6	0.63	0.69	0.77	0.79
$(1 - \frac{\beta_{w/s}}{\beta_s})\ 100\%$	40	37	31	23	21

It can be seen that the swimbladder contributes greatly toward the reflection of ultrasound at low frequencies and to a lesser degree at higher frequencies. In the latter case the major part is played by tiny air bubbles contained in the body of the fish.

Comparing our results with the data of other authors, we find that Cushing and Richardson have concluded that from 40 to 80 per cent of a signal received from a live cod came from the swimbladder. Harden Jones and Pears who experimented with perch found that 50 per cent of the signal is produced by the swimbladder which in this fish accounts for about 7 per cent of its volume.

The results of Beverton & Blacker are in close agreement with those of Harden Jones and Pears at a frequency of 14.5 kc/sec. Harden Jones found that the relationship between the strength of the echo signal and the length of the fish (in this case cod 20 to 80 cm) is approximately linear. The data of these authors are not in agreement with our results.

In horizontal echo-sounding of homogeneous objects of restricted extension a decrease of the pulse length will reduce the level of reverberation proportionally without altering the strength of the echo signal. But a fish school can not be likened to a solid massive homogeneous object. It is a cumulation of many small reflecting objects (targets), so that in the echo-sounding of fish schools the relationship between reverberation and intensity of pulse length will bring about a considerable decrease of the intensity of the echo signal.

The elucidation of the relation between intensity of echo signal given by a fish school and length pulse is therefore a very actual problem. The intensity of echo signals from submerged objects is determined by the following known equation:

$$\cdot = \frac{P_a \gamma R_e^2\, 10^{-0.2\,\delta r}}{16\,\pi\, 2\, r^4}$$

where

P_a—acoustical power

γ—coefficient of concentration of the transducer

R_e—radius of the equivalent sphere of the reflecting object (target)

r —distance from transducer to object

δ —coefficient of spatial attenuation

Yet this equation does give the relation of intensity of the echo signal to the pulse length, if it is not presumed to be concealed in the value of the radius of equivalent sphere. In a series of experiments carried out at sea on live horse mackerel, an attempt was made to find out the relationship between the signal given by fish and the length of fish.

Adequate statistics permitted to achieve a high degree of precision of our acoustical measurements during which 740 cycles of measurements (recorded on oscillograms) were carried out on three fish schools of different numerical strength. All the measurements were made at a frequency of 94 kc/sec. The diagram in Fig 4 based on our acoustical investigations shows that the radius of the equivalent sphere of a fish school R_e is proportional to the square root of the value of the pulse length τ.

$$R_e = R_1 \sqrt{\tau}$$

The coefficient of proportionality R_1 is numerically equal to the radius of the equivalent sphere of a fish school at a pulse length of 1ms. With increasing pulse length the scattering space element increases and when sounding a fish school in a vertical direction, increases the strength of signal. By substituting the obtained values from the equation given above:

$$I = \frac{P_a \gamma (R_1 \sqrt{\tau})^2 10^{-0.2\delta r}}{16\pi r^4} = \frac{P_a \gamma R_1^2 \tau 10^{-0.2\delta r}}{16\pi r^4}$$

In this case, as in the formula for the intensity of reverberation, the intensity of the echo signal is proportional to the pulse length. Physically this is quite comprehensible as a fish school is a cumulation of small scatterers, generating useful reverberation; echo signals returned by fish schools are therefore not only increased in amplitude, but obviously prolonged too. Records of fish schools on echograms are therefore overestimated in the vertical direction, and may even sometimes extend to beyond the bottom line (Fig 3). The diagram in Fig 4 illustrates the increase of R_e with increasing τ. This increase is especially pronounced in huge concentrations of fish. The apparatus used in our experiments allowed us to carry out measurements at pulse length ranging from 0.1 ms to 2 ms and it may be inferred that the regularity will be apparent at higher values too. Our results can be used in the designing of hydroacoustical fishfinders:

(a) For selecting optimum pulse length according to special requirements. Thus for echo sounders, employed for fishfinding in pelagic fisheries greater pulse lengths may be used; this will permit economies on the power P_a, and hence on the size of the apparatus; the optimum pulse lengths will be that at which $\frac{c\tau}{2}$ is equal of the thickness of the fish school in the direction of location.

(b) As initial data for the calculation of the radius of equivalent spheres of schools in conformity with other pulse length; this is necessary for calculations of the range of fish finding equipment.

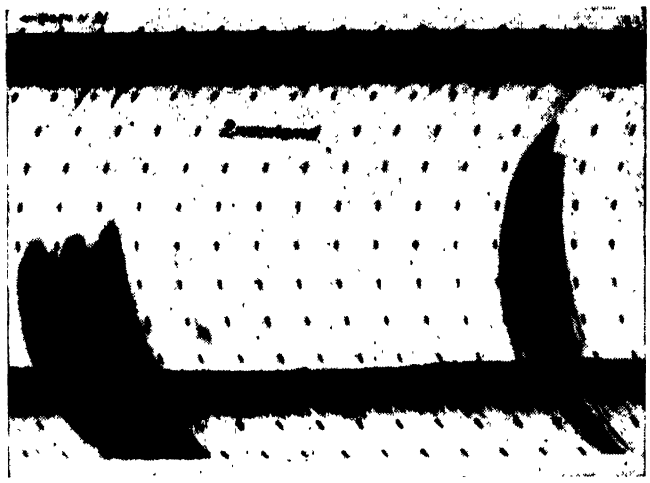

Fig 3. Record of fish schools producing a strong reverberation (echo recorded under the ground).

During the passage of ultrasound pulse through fish schools the decrease of energy, characterized by the coefficient of attenuation, will be greater than in a relatively homogeneous marine medium, due to losses caused by the fish bodies. An ultrasound pulse passing through a fish school may be entirely attenuated and the echo recorder will not record the bottom beneath the school even at relatively shallow depths. In horizontal echo-sounding the ultrasound pulse may encounter simultaneously several fish schools of great extension; if the pulse is not strong enough it will be attenuated before

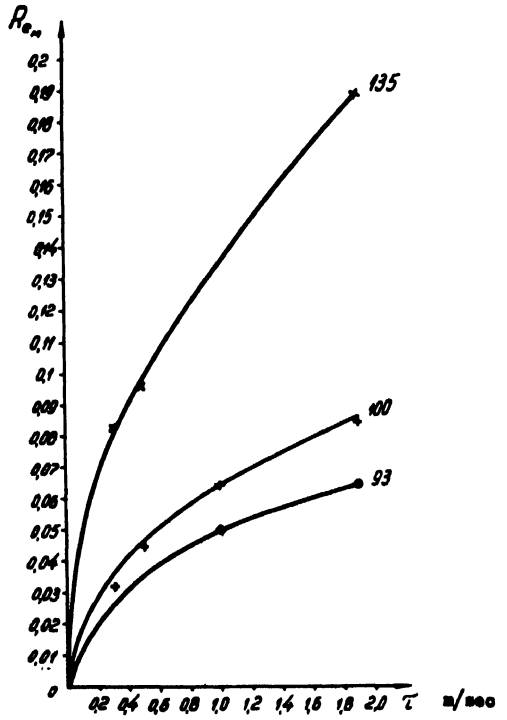

Fig 4. Relation of radius of equivalent sphere to duration of pulse observed on three fish schools of different numerical strength.

giving an echo from each individual school. This may occur also for a single but very compact school widely extended in the direction of location.

Records of kilka (sprat) schools shown in Fig 5,

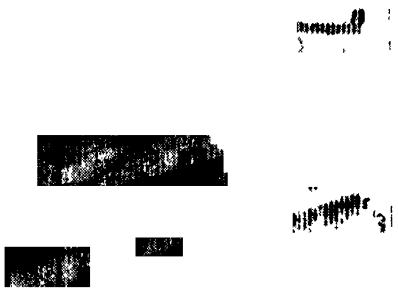

Fig 5. Record of fish schools by a hydro-locator at different values of emitted power.

were taken in the Black Sea at different values of transmitting power. With a maximum power the echo sounder recorded five schools disposed one behind the other. At a ten times lower power the sounder recorded only four schools and the last of them only slightly and partly (about half of the actual thickness of the school). Even at maximum power the fifth school was only faintly marked. However, when the vessel approached nearer this last school was fully and clearly recorded even at a five times lower power.

Special experimental investigations were carried out aimed at a quantitative assessment of the attenuation of ultra sound in fish schools of different degrees of concentrations. The diagram in Fig 6 based on acoustical measurements, shows the relation of attenuation of ultrasound to frequency for four different concentrations of fish schools. We see that the coefficient of attenuation increases with increasing concentration, i.e. with an increase of biomass per cent of water volume.

The Japanese scientist, Hashimoto, suggests that since the losses of ultrasonic waves reflected by fish schools decrease with increasing frequencies, it be inferred that loss of propagation will increase with increasing frequency. This assumption has been confirmed by our results, though the values recorded by Hashimoto are significantly higher and the coefficients of attenuation are not physically equivalent and consequently not directly comparable. Losses of propagations consist of two components: attenuation of ultrasound in the fish

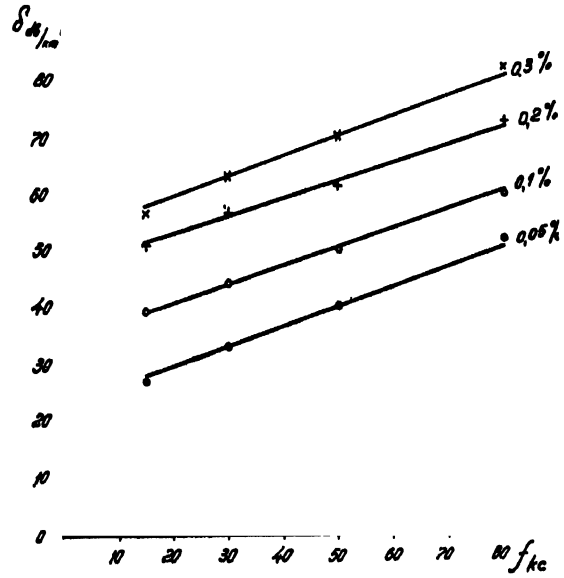

Fig 6. Extinction of ultrasound in fish schools of different concentration in relation to frequency.

and water medium and scattering. An important part of the energy of a sonic wave reaching a fish school is scattered and lost uselessly, and only a small part of the energy of a transmitted pulse return to the receiver. Consequently an ultrasonic pulse passing through a fish school will be weakened not so much by attenuation in the medium, but rather by scattering by the fish bodies. At a certain concentration of the school the losses of propagations may become so high that the ultrasonic pulse will be completely attenuated.

Frequency Analysis of Marine Sounds

Abstract

As fundamental data preliminary to the development of methods for detecting, luring or driving away fish schools with sound, sounds of marine animals and ambient noises in the sea have been studied and analyzed. The frequencies of sounds made by whale, dolphin, drumfish, spotfish, croaker, gurnard, lobster and shellfish, and swimming sounds of yellowtail, squid, surf-perch and filefish were analyzed. Each sound showed a spectrum characteristic of the species. Recorded sounds of risso's dolphin are in the range of 150–5,000 c/sec; drumfish gave a maximum pip at 500 c/sec; spotfish 650 c/sec; croaker 250–800 c/sec; and gurnard 100–400 c/sec. Drumfish, spotfish, croaker and gurnard, etc., produce their sounds with their air bladders. Yellowtail gave pips in the range of 150–3,000 c/sec. The swimming sound of squid schools was at 1,000–2,000 c/sec. Lobster produces sounds at the base of its antenna with maxima at 180–4,000 c/sec, with intensive components in the ultrasonic range. Ambient sea noises of Aburatsubo Bay and Kurihama Bay, Kanagawa Prefecture, Izu Ajiro and Shimoda Shizuoka Prefecture, Choshi Kurohae, Chiba Prefecture and others were analyzed. The spectra differed with the areas and depth of water.

by

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Au cours d'une étude effectuée en vue de développer des méthodes pour détecter, attirer et effrayer des bancs de poissons par le son, les sons d'animaux marins et bruits ambiants de la mer ont été étudiés et analysés. Les fréquences des sons produits par les baleine, dauphin, "drumfish", "spotfish", maigre, grondin, homard et crustacés ont été analysées. A chaque espèce correspond un spectre caractéristique de sons. Les sons émis par les squales ont une portée de 150 à 5000 c/sec; par le "drumfish" un maximum de 500 c/sec; le "spotfish", 650 c/sec; le maigre, 250–800 c/sec et le grondin, 100–400 c/sec. Les "drumfish", "spotfish", maigre et grondin produisent leurs sons avec leurs vessies natatoires. Les sérioles donnent des sons entre 150 et 3000 c/sec. Le bruit de nage des bancs de calmars était de 1000 à 2000 c/sec. Les crustacés produisent des sons à la base de leurs antennes avec un maximum de 180–4000 c/sec avec des composants complexes intensifs, à la fréquence ultrasonique. Les bruits ambiants dans les baies de Aburatsubo, Kurihama, Kanagawa Prefecture, Izu Ajiro Shimoda et Shizuoka Prefecture, Choshi Kurohae, Chiba Prefecture et dans d'autres eaux du Japon ont été analysés et l'on a trouvé que les spectres de sons différaient selon le lieu et la profondeur de la mer.

Extracto

Por ser datos básicos preliminares para la formulación de métodos para localizar, atraer o rechazar cardúmenes con sonidos, se han estudiado y analizado los que emiten los animales maronis y los ambientales en le mar. So analizaron las frecuencias de los sonidos emitidos por ballenas, delfines, "drumfish", "spotfish", roncador, perlón, bogavante y mariscos, y los sonidos que hacen al nadar el jurel amarillo, calamar, "surf-perch" y "filefish". Cada sonido tenía un espectro característico de la especie. Los sonidos registrados de las ballenas están en la gama de 150 a 5.000 c/seg; el "drumfish" dio una señal máxima de 500 c/seg "Spotfish" 650 c/seg; roncador de 250 a 800 c/seg; y perlón de 100 a 400 c/seg. Estos peces producen sus sonidos con la vejiga natatoria. El jurel amarillo dio sonidos en la gama de 150 a 3.000 c/seg. Los sonidos producidos por cardúmenes de calamares en movimiento eran de 1.000 a 2.000 c/seg. El bogavante produce sonidos en la base de sus antenas en la gama de 180 a 4.000 c/seg, con componentes intensivos en la gama ultrasonora. Tamibon se registraron y analizaron ruidos marinos ambientales en las bahías de Aburatsubo y Kurihama, en la Prefectura de Kanagawa, en las Prefecturas de Izu Ajiro y Shimoda Shizuoka, Choshi Kurohae, Prefectura de Chinba y otros lugares. Los espectros variaban con el lugar y profundidad del agua.

METHODS of detecting, luring or driving away fish schools by sound are being investigated by the authors. To obtain fundamental data, the intensity and the frequency spectra of sounds produced by marine animals and ambient noises in the sea were studied, using a hydrophone.

A special hydrophone was manufactured. Its characteristics are flat with a deviation less than 3 db in the frequency range from 50 to 35,000 c/sec as shown in

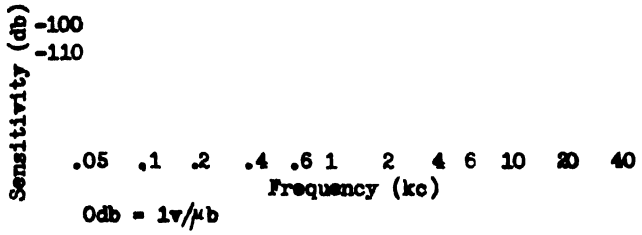

Fig 1. Sensitivity-frequency characteristics of hydrophone.

Fig 1. This hydrophone is made of barium titanate. It is cylindrical with a diameter of 5.5 cm and is enclosed in an acoustic rubber case filled with castor oil.

The tape recorder used was Sony 552-type, the frequency characteristics of which are flat in the range from 50 to 10,000 c/sec. The Panoramic Analyser used was a super-heterodyne type with an analysing range of 40 c to 20,000 c/sec.

The endless tape was made by joining several pieces on which a single sound was recorded at the same level with Ampex 307-type recorder (the frequency characteristics are flat in the range of 150 c to 35,000 c/sec). A photograph of several sweeps on the cathode ray tube of the analyser was taken, by playing back the endless tape. Sea noises were analysed by playing back the tape recorded in the sea.

Analysis of sounds of sea animals

Fig 2 to Fig 13 show results of analysis of sounds made by sea animals. Fig 2 shows the spectrum of low-pitch sound of Risso's dolphin. The maximum pip is nearly at 2,500 c/sec. The second pips, which are lower than the

Fig 2. (Left) Low-pitch sound of Risso's dolphin; 3. (right) High-pitch sound of Risso's dolphin.

former by 17 db, are at 200 c and 250 c/sec. Fig 3 shows the spectrum of high-pitch sound of Risso's dolphin which is different from Fig 2. The maximum pip is between 3,000 c and 5,000 c/sec; and the second maximum, which is lower than the former by 9 db, is at about 250 c/sec. These sounds are intensive even in the range of ultrasonic waves[1]. Fig 4 shows the spectrum of drumfish with the maximum pip at 500 c/sec. Fig 5 is for spotfish. The

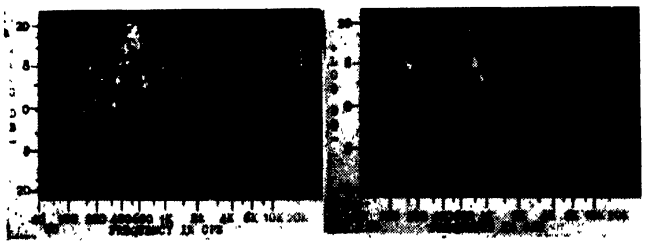

Fig 4. (Left) Spectrum of drumfish and 5 (right) Spectrum of spotfish.

maximum pip is nearly at 650 c/sec. The second maximum, less than the former by about 4 db, is at about 150 c/sec. Fig 6 is for croaker. The maximum is nearly at 250 c/sec. The second maximum, less than the former by 14 db, is nearly at 800 c/sec. Fig 7 is gurnard and shows the maximum pip between 100 c and 400 c/sec.

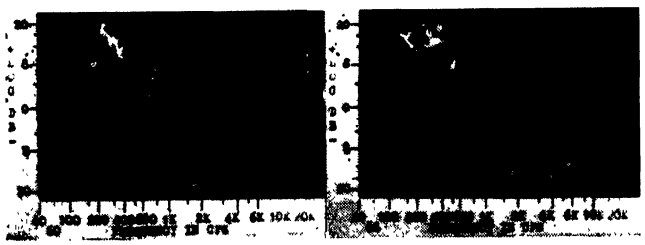

Fig 6. (Left) Spectrum of croaker; 7. (right) Spectrum of gurnard.

Drumfish, spotfish, croaker, gurnard etc., produce their sounds with their air bladders. These sounds differ with species. Their maximum pips are at frequency ranges lower than 1,000 c/sec.

In the spectrum of swimming sound of yellowtail (Fig 8), the maximum pips are at 150–600 c/sec, and at about 1,200 c/sec, respectively, and the second maximum, less by about 4 db, is at 2,000 c/sec, and the third maximum, less than the second by 10 db, is at about 3,000 c/sec. In the spectrum of swimming sound of squid

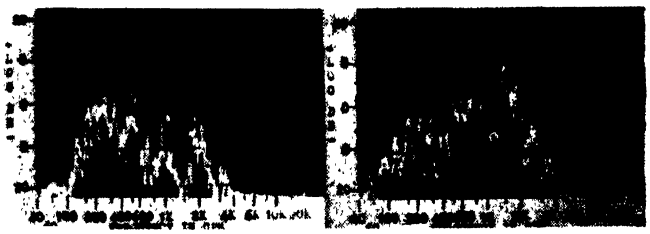

Fig 8. (Left) Swimming sound of yellowtail; 9. (right) Swimming sound of squid school.

schools (Fig 9), the maximum is at 1,000–2,000 c/sec. Fig 10 shows the swimming sound of surf-perch which has the maximum at about 300 c/sec and the second maximum, less by about 14 db, is at 1,500 c/sec. Fig 11 shows

Fig 10. (Left) Swimming sound of a surf-perch school; 11. (right) Swimming sound of filefish school.

the swimming sound of filefish which has the maximum at 1,000 c/sec and its second maximum, less by 8 db, is at 2,000 c/sec.

These swimming sounds have spectra characteristic of the species of fish, and all of them have rather high-frequency components.

Lobster produces sounds at the base of its antenna. The spectrum is shown in Fig 12, which has its maxima at about 180, 700 and 1,500 c/sec, respectively, and the second maximum, less by 6 db, is at 4,000 c/sec. These sounds have intensive components in the ultrasonic range.

Fig 13 shows the spectrum of sounds of shellfish

Fig 12. (Left) Sound produced by antenna of lobster; 13. (right) Sound of bubbles blown by shellfish.

produced when it blows bubbles; this has its maxima at 1,500–1,700 c/sec and 3,500 c/sec, respectively. Frequency components in the ultrasonic range are also noted.

Frequencies at which pips are maximum in these spectra are shown in Table I. The order of magnitude of pips is marked by (1), (2), (3).

Table I—Frequency at which pip is maximum

Species of fish and kind of sound		Frequency (c/s)
Risso's dolphin	low-pitch	(1) 2,500 (2) 200–250
	high-pitch	(1) 3,000–5,000 (2) 250
Drumfish		500
Spotfish		(1) 650 (2) 150
Croaker		(1) 250 (2) 800
Gurnard		100–400
Swimming sound	Yellowtail	(1) 150–600, 1,200 (2) 2,000 (3) 3,000
	Squid	1,000–2,000
	Surf-perch	(1) 300 (2) 1,500
	Filefish	(1) 1,000 (2) 2,000
Sound produced by antenna of lobster		(1) 180, 700, 1,500 (2) 4,000
Sound of bubbles blown by shellfish		1,500–1,700, 3,500

Spectra of sea noises of Aburatsubo Bay and Kurihama Bay (Kanagawa Prefecture), Izu Ajiro and Shimoda (Shizuoka Prefecture), and Choshi (Chiba Prefecture) are shown respectively in Fig 14 to Fig 18. It will be seen from these figures that spectra differ with water areas. Measured values of sound intensity also differ with water areas as shown in Table II. Frequency components in the ultrasonic range are also noted.

Effects of depth on ambient noises in the sea were measured at Shimoda. Fig 19 is the spectrum at Kojirahama (sea depth is 3 m), while Fig 20 is the spectrum 1,500 m away from the shore (sea depth is 20 m). Sound intensity is greater near the coast.

Fig 14. (Left) Sea noises of Aburatsubo Bay, Kanagawa Prefecture 15. (right) Kirihama Bay, Kanagawa Prefecture.

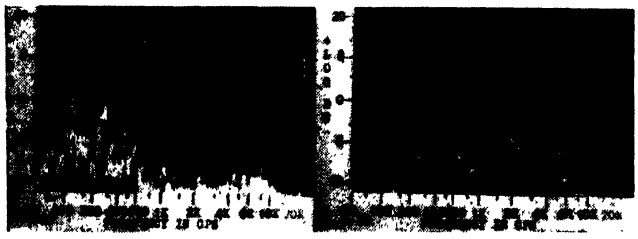

Fig 16. (Left) Ajiro, Shizuoka Prefecture; 17. (right) Choshi Chiba Prefecture.

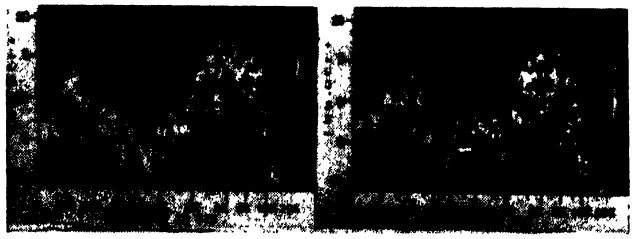

Fig 18. (Left) Entrance of Nabeta Bay, Shimoda, Shizuoka Prefecture; 19. (right) Shimoda Kojirahama (sea depth is 3 m) Intensity is 12.3 × 10_{13} W/cm_3.

Fig 20. Offing 1,5000 m away from Kojirahama (sea depth is 20 m). Intensity is 1.80 × 10_{13} W/cm_3.

Table II—Pressure and intensity of sea areas

Areas	Date	Sound pressure (bμar)	Sound intensity (10^{-13}w/cm^2)
Aburatsubo Bay, Kanagawa Prefecture	10.55 hrs (17/12/59)	4.60–5.60	14.10–21.0
Ajiro, Shizuoka Prefecture	08.20 hrs (4/2/60)	0.50–1.00	0.17– 0.67
Shimoda Nabeta Bay, Shizuoka Prefecture	15.50 hrs (2/8/59)	3.63	8.80
Entrance of Nabeta Bay	16.30 hrs (2/8/59)	3.13	6.50
Shimoda Kojirahama	17.30 hrs (2/8/59)	4.30	12.3

Conclusions

(a) The spectrum of sound produced by a marine animal is characteristic of the species, so these sounds can be used for detecting, attracting or repelling fish schools. The authors are now studying such methods.

(b) Spectra of ambient sea noises differed with the areas and depth of water where the analyses were made.

Acknowledgments

The authors acknowledge assistance received from M. Nishimura, Fishing Boat Laboratory, Fisheries Agency, Tokyo, and Assistant Professor K. Kusaka of Tokyo University.

Reference

Hashimoto, T., and Maniwa, Y., Noise of creatures in sea in range of ultrasound. *Technical Report of Fishing Boat Laboratory* No. 12. 1958.

Identifying Pacific Coast Fishes From Echo-Sounder Recordings

Abstract
Echo-sounder sensitivity has been developed more rapidly than the capabilities of the average operator to use these improvements to identify the fish species pictured by them. It is time the fishing industry made better use of the tools now available for more economical fishing operations. Constant use of echo sounders and careful observations of the traces they make can provide valuable information on the length and density of specific fish concentrations below the vessel. Examples are given of echograms showing characteristic traces of hake, rockfish and anchovy.

Identification de poisson par des enregistrements d'echo-sondeur sur les cotes du Pacifique

Résumé
La sensibilité des échos-sondeurs s'est developpée plus rapidement que les capacités des opérateurs à l'emploi des ces instruments perfectionnés pour l'identification des espèces de poissons enregistrées sur les graphiques. Il est nécessaire que l'industrie de pêche fasse un meilleur usage de ces instruments, pour obtenir des opérations plus économiques. L'utilisation continue des échos-sondeurs et l'observation minutieuse des tracés graphiques peuvent en effet, donner des informations importantes sur la longueur et la densité de certaines concentrations de poissons, sous le bateau. Comme exemples, l'auteur communique des échogrammes montrant les tracés caractéristiques de merlus, rascasses de fond et anchois.

Identificacion de peces de la costa del Pacifico con registros de la ecosonda

Extracto
La sensibilidad de las ecosondas ha aumentado más rápidamente que la capacidad del operador corriente de emplear estas mejoras para identificar las especies de peces que señalan. Ha llegado el momento de que la industria pesquera emplee mejor los aparatos de que dispone para pescar más económicamente. El uso constante de las ecosondas y la observación cuidadosa de los trazos pueden facilitar valiosa información de la longitud y densidad de concentraciones de peces específicos debajo del barco. Se dan ejemplos de ecogramas que muestran trazos característicos de merluza, gallineta y anchoa.

ALTHOUGH echo-sounder sensitivity has been greatly improved in recent years, little progress has been made at identifying the traces recorded on echo-sounding equipment.

On Pacific coast trawlers recently there has been a trend to replace old equipment with newer, more sensitive units.

Refinements in recording-type echo sounders have prompted wider use of these instruments to find fish and, in some instances, to identify these fish by the characteristic traces made by different species on the recording paper. Several trawler captains use echo sounders to provide permanent records of their fishing trips.

Echograms provided by Mr. Harry Barrington, master of the trawler *Christine*, illustrate their use for identifying fish schools to species. Mr. Barrington uses a Kelvin Hughes model MS 29 Echo Sounder while fishing primarily for rockfish (Fam. *Scorpaenidae*) out of Santa Barbara, California. Since rockfishes have well-developed swim bladders and school near the bottom, they make excellent targets for detection with echo sounders.

The traces were made during otter trawling operations and species determinations were made by examining the catch upon completion of the haul.

by
E. A. Best

Marine Research, Californian
Department of Fish & Game

Two rockfishes produced a characteristic trace: chilipepper, *Sebastodes goodei*, and stripetail rockfish, *Sebastodes saxicola* (Figs. 1 and 2). Chilipeppers are

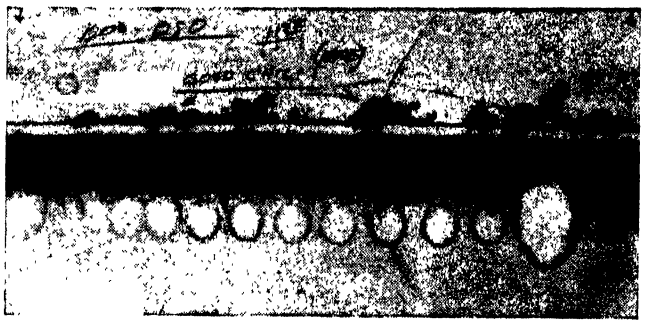

Fig. 1. Echo-sounder tracings of chilipepper, Sebastodes goodei.

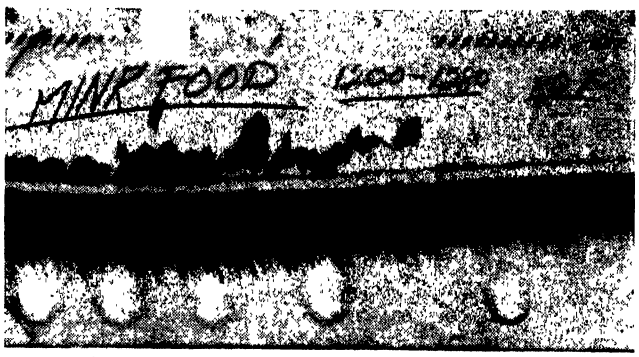

Fig. 2. Echo-sounder tracings of stripetail rockfish. Sebastodes saxicola.

desirable market fishes and make up nearly 40 per cent of the rockfish landings at Santa Barbara. Stripetail rockfish rarely exceed 10 inches in length and are used primarily as animal food.

Pacific hake, *Merluccius productus*, are often abundant and characteristically show up on echograms as narrow schools, often extending several fathoms above the bottom (Figs. 3 and 4). Mr. Barrington's hake traces are similar to those reported for hake off the Washington coast during daylight hours (Schaefers and Powell 1959). After dark, hake schools apparently break up and the fish become scattered in the mid-depths.

Fig. 3. Echo-sounder tracings of Pacific hake, Merluccius productus.

Fig. 4. Echo-sounder tracings of Pacific hake, Merluccius productus.

Pelagic fish are often abundant over the trawling grounds. One echogram showed a dense concentration of anchovies, *Engraulis mordax*, at mid-depth with schools of hake near the bottom (Fig. 5).

Some recent electronic echo-sounder installations have included instruments using a cathode ray tube (C.R.T.) to present visually the returning echoes. The success of these units depends to a great extent upon the

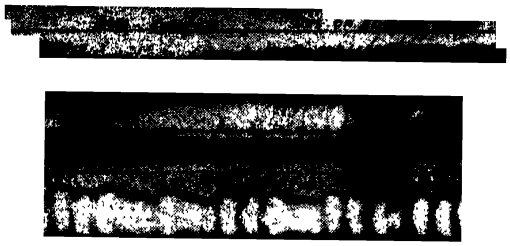

Fig. 5. Echo-sounder tracings of anchovy, Engraulis mordax *at mid-depth with hake showing near the bottom.*

operator's ability to interpret and remember the images produced on the C.R.T. These units have been used to locate and determine the extent of bottomfish concentrations, particularly rockfish, *Sebastodes* spp.

By determining the extent of a fish concentration and adjusting individual trawl hauls to the length of the school, rather than some arbitrarily chosen time unit, more economical use of fishing time has been realised.

There has been little success in detecting flatfish concentrations with cathode ray tube sounders, but refinements may someday soon make such a task possible.

References

Schaefers, E. A. and Powell, D. E.: Correlation of midwater trawl catches with echo recordings from the northeastern Pacific. *In* Modern fishing gear of the world, edited by Hilmar Kristjonsson, pp. 517-522. London, Fishing News (Books) Ltd., 607 pp. 1959.

Echo-Sounding Through Ice

Abstract
The echo traces of the bottom of, and fish schools in, a frozen lake could be obtained with ease and speed by determining positions on and by sounding through the surface ice. The transducers were brought into good contact with the ice by removing the snow and pouring a cup full of water. Using 200 kc and 400 kc transistorised recording echo sounders, it was possible to obtain echo traces of pond-smelt, a very slender fish about 11 cm long, through surface ice. The transmission loss of ultra-sound in ice was almost linear with the thickness of ice. In artificial ice it varied from 0·25 db/cm at 20 kc to 0·60 db/cm at 200 and at 400 kc, while in natural ice on the surface of the frozen lake studied it was 0·40 db/cm at both 200 and 400 kc. The sound velocity through ice was found to be 3,120 m/sec. The results for natural ice are claimed to be valid only under the conditions of the experiments reported.

Echo sondage a travers la glace

Résumé
Les indications de fond et des bancs de poissons dans un lac glacé ont été obtenues facilement et rapidement, en des points prédéterminés par écho-sondage à travers la glace. Un bon contact avec la glace fut assuré par l'enlèvement de la neige suivi d'un rinçage avec un peu d'eau. Grâce à des écho-sondeurs à transistors de 200 à 400 kc, il a été possible d'obtenir des échos de sauclet, un petit poisson mince, de 11 cm de long. Les pertes de transmission en ultra-sons dans la glace étaient presque linéaires avec l'épaisseur de la glace. A travers la glace artificielle les pertes de transmission variaient entre 0·25 db/cm à 20 kc et 0·60 db/cm à 200-400 kc tandis qu'à travers la glace naturelle du lac glacé étudié, les pertes de transmissions ont été de l'ordre de 0·40 db/cm à 200 et à 400 kc. La vitesse du son à travers la glace atteignait 3·120 m/sec. Les résultats obtenus pour la glace naturelle, cités plus haut ne sont valables que dans les conditions de l'expérience.

Ecosondajes a través del hielo

Extracto
Los trazos de los ecos de los cardúmenes y del fondo de un lago helado se obtuvieron con facilidad y rapidez determinando sus posiciones con respecto a la superficie del hielo y a través de ella. Los transductores se pusieron en contacto con el hielo quitando la capa de nieve y vertiendo un poco de agua para nivelar la superficie. Empleando ecosondas registradoras transistorizadas de 200 kc y 400 kc se pudieron obtenur ecos de "pond-smelt", que es un pez muy delgado de unos 11 cm. de longitud, a través del hielo. La pérdida de ultrasonidos por transmisión a través del hielo estaba casi en proporción aritmética con el espesor de éste; en hielo artificial variaba de 0·25 db/cm a 20 kc hasta 0·60 db/cm a 200 y a 400 kc, en tanto que en hielo natural en la superficie del lago estudiado era de 0·40 db/cm a 200 y 400 kc. La velocidad de transmisión del sonido por el hielo es de 3,120 m/seg. Los resultados para el hielo natural se afirma que sólo son válidos en las condiciones de los experimentos de que se da cuenta.

by
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and
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and
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Shibara Technical Institute, Tokyo

Fig. 1. Top. *The small transistorised 400-kc echo sounder and* below *the 200-kc echo sounder (Fish camera).*

ACCURATE soundings of water depths needed for bottom surveys and any changes in the bottom profile of water reservoirs may be difficult and requires specific efforts because of the drifts of boats due to wind and current. It may therefore be more convenient to take soundings when the water body is covered with ice. The common method had so far been to break holes into the ice on each spot, but it would be a great simplification if the soundings could be taken through the ice.

The authors, therefore, conducted experiments in echo sounding from the surface ice of Lake Haruna, Gumma Prefecture, Japan, in January and February 1962 to find out if echoes of the bottom and of fish can be obtained and to furnish some of the necessary data.

Two very small and compact transistorised echo sounders were used. One was a 400-kc type with a sounding range of 75 m, manufactured by Furno Electric Co.; the other was a 200-kc type with a sounding range of 65 m manufactured by Nippon Electric Co., Ltd.

At regular points, the transducers of the echo sounders were brought into good contact with the ice by pouring about a cup full of water (Fig. 2). (Water was found better for contact than castor oil.) Fig 3 shows echo traces obtained from the lake bottom. The traces for each point are horizontal lines as the transducers were stationary. The transverse section of the lake is drawn according to the echo soundings. The surface ice was 25 cm thick and it would have been difficult to make

Fig. 2. Application of the echo-sounder transducers to the ice surface. Proper acoustical contact is secured by bringing water between the surfaces of the transducers and the ice.

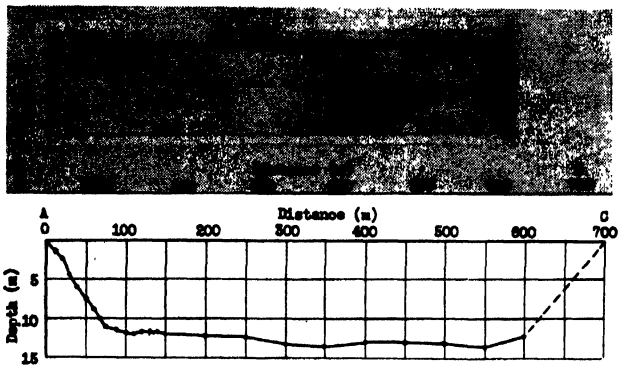

Fig. 3. Bottom traces obtained at some of the sounding positions (A) and the bottom profile under the surveyed line drawn according to the echo sounder (B).

holes through it. By sounding through the ice this difficulty was eliminated. The time necessary to determine about 24 positions and to take the soundings was only 1 hr 25 min. With the same method, also echo traces of pond-smelt were obtained with the 400-kc fish finder (Fig. 4 and Fig. 5). The ice was 25 cm and 31 cm thick respectively. Schools of pond-smelt are shown close to the bottom (Fig. 4) or scattered from the surface to the bottom (Fig. 5). Some of the pond-smelt were caught and found to be about 11 cm long.

Fig. 4. Echo traces of pond-smelt (Hypomesus olidus) *in shallow water near the bottom obtained through 25 cm thick ice.*

The transmission loss in artificial ice was measured for 28, 100, 200, and 400 kc. In a 25-m long water tank with a cross-section of 50×50 cm, the transmitting and

Fig. 5. Echo traces of pond-smelt (Hypomesus olidus) *in deeper water obtained through 31 cm thick ice.*

receiving transducers were put opposite each other and ice plates of varying thickness were placed between them. The sound pressure of the pulses received through the ice was measured. The graph (Fig. 6) shows the relation between the thickness of the ice plates and the transmission loss; the measured values are nearly on a straight line.

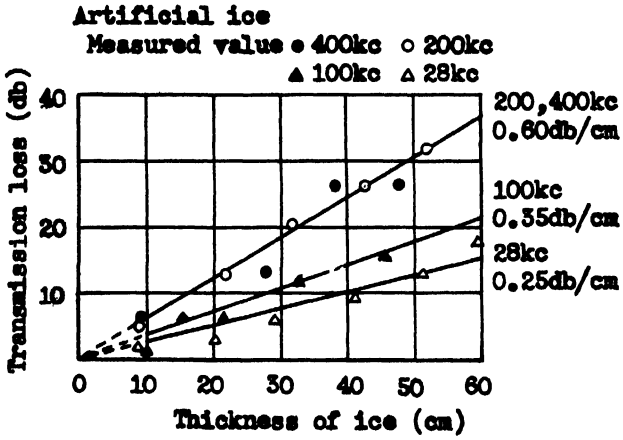

Fig. 6. Transmission loss in artificial ice of ultrasound of 28, 100, 200 and 400 kc versus thickness of ice.

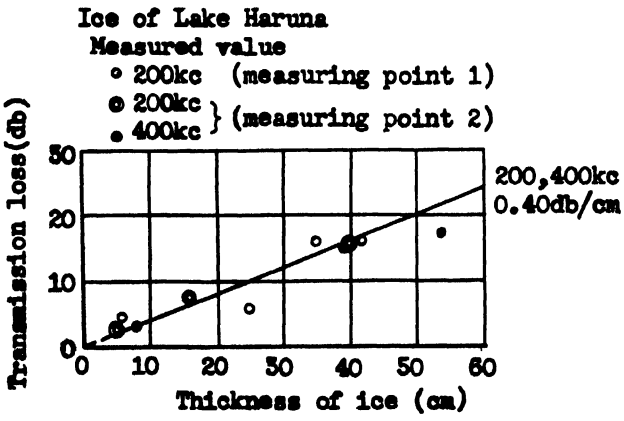

Fig. 7. Transmission loss in the natural ice of Lake Haruna of 200 and 400 kc versus thickness of ice.

The transmission loss in natural ice was measured for various thickness of ice. It is emphasised that these values are valid only under the conditions of the experiments reported here; they may well be different under other conditions of snowfall and freezing.

To determine the velocity of sound in ice, the transducers of the 400-kc echo sounder were placed on the surface of an ice block 53 cm high, and the time taken for the echoes to return from the opposite surfaces was measured. By this method, the sound velocity was found to be 3,120 m/sec.

Discussion on Fish Detection

R. E. Craig

Mr. R. E. Craig (U.K.) Rapporteur: Direct acoustic methods seem to offer the most immediate aid, but we must not be blind to other possibilities. Alverson and Wilimovsky call attention to the possibilities of indirect methods of using acoustic techniques, by automatic stations linked by radio to ship or shore. These authors also mention the possibility of developing optical methods of detection. I think it is important to see how optical pulse methods might compare with acoustic ones.

I would like to mention the relation between range and frequency in ordinary sonar. Signal strength from a single target decreases by about 12 decibels for each doubling of the range, due to the geometrical spreading of the sound waves. So, for a perfect medium, we can show the relationship by a simple curve like (a) in Fig. 1.

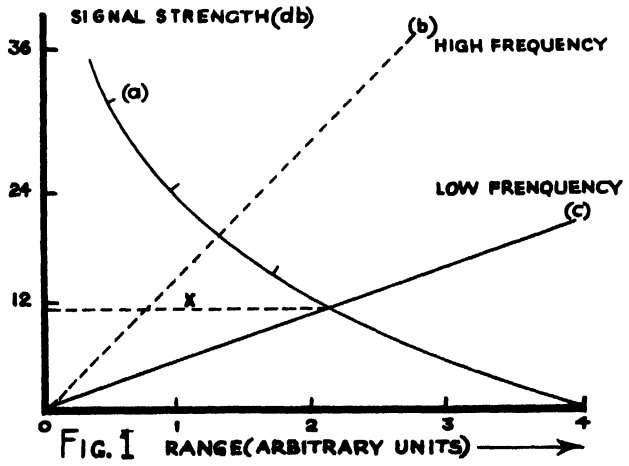

FIG. 1

In addition to this reduction of signal by spreading we have a loss due to absorption, which is directly proportional to the range, as curve (c). So if the minimum detectable signal is, on this scale, zero, the range is given by the distance X. For higher frequencies the absorption loss is greater, and so the range is less. Because of the dependence of absorption on frequency, it turns out that the range obtainable with any given frequency is limited. I illustrate this in a very simple and approximate graph.

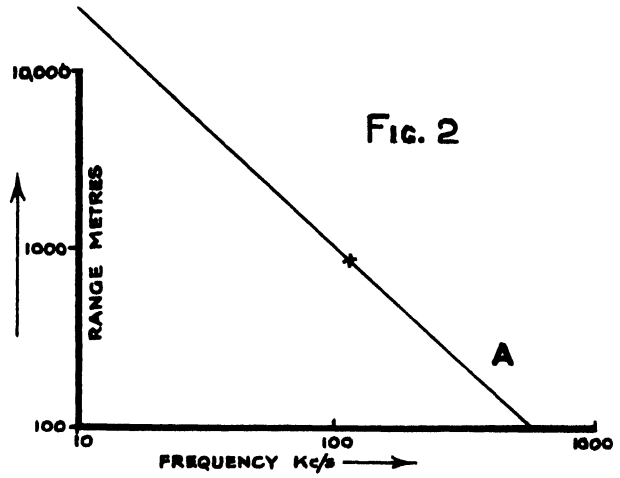

FIG. 2

It is in the region of high frequency and short range, that optical methods might have value. Absorption of light in the sea is very variable, but is of the same order as for megacycle acoustic frequencies. Because of the very pure spectrum that could be used optically, ranges of one or two hundred metres or so seem indeed possible, and the great advantage is that light can pass easily through the air-water interface and so optical methods could be used from aircraft. Also, the rate of transmission of light is so high that vastly more information per second could in principle be gathered.

On the other hand it does not seem likely that range resolution could be as good as is given by acoustic methods.

In matters of more immediate importance to us today, there has been progress since the last Gear Congress. First, there has been a considerable extension of echo sounding to smaller and cheaper boats, encouraged by the production of small, relatively cheap echo sounders. Secondly, there have been considerable advances in the tactical use of sonar in deep sea pelagic fisheries and in trawl fisheries.

The first of these, unfortunately, is not mentioned in any papers, and I would be happy if FAO would produce a brief survey on this topic when the papers are published.

On the use of sonar, Schärfe, Steinberg, and Mohr show that the problems of handling a headline transducer or netzsonde can be solved. They show how fish behaviour can be studied by this method, in intimate relation to the movements of the trawl, and how dependent the development of pelagic trawling and pelagic trawl design has been on the use of this technique. These papers are the beautiful result of instrumentation well used, bringing out from comparatively simple techniques, information of vital importance in fish behaviour and gear design.

Again, Jakobsson describes the successful use of sonar in purse seining. The emphasis here is really on fishing tactics, and this brings in Vestnes on training in the use of sonar. These two papers are most timely in bringing out the gap that can exist between development of equipment, and its successful use. As techniques develop, so the need for the right kind of training will develop also.

There are three papers on identification of echo traces. These are the papers by Lenier, Nishimura and Best, and they include excellent reproductions of various echo traces of known origin. Nishimura also considers the desirable charac-

teristics of a sounder for tuna fishing, and comes to the conclusion that a very powerful but otherwise conventional machine is suitable. To complete the topic of applications of sounding, Kawaguchi, Hirano and Nishimura show that it is possible to study the behaviour of longlines by this means.

The other papers in fish detection deal with new equipments on the one hand, and fundamental acoustic studies on the other. Taking the fundamental studies first, we have in this group an important paper by Hashimoto and Maniwa on the frequency analysis of marine sounds. This begins to lay a serious foundation for fish detection by passive listening, either directly or via a radio link. The authors give the frequency spectrum from a number of living things in the sea, and some detail of the background against which such sounds would have to be detected.

The same authors, in collaboration with Omoto and Noda, give details of the acoustic parameters of ice, and show the practicability of echo sounding through ice, a technique that could, on occasion, have practical value.

Finally, Shishkova treats the relationship between individual fish echoes, and the echoes from shoals of such fish.

Of the four papers on new equipment two—those by Gerhardsen on the research sonar, and by Ellis, Hopkins and Haslett on the Humber echo sounder—are in some ways similar. Each presents a serious attempt to build the most efficient possible machine on essentially conventional lines.

Both machines are characterised by very high transmission power (about eight kW peak) and by the provision of the best display methods available. To pick just one special feature, I expect most engineers will feel that the production of a satisfactory bottom-locked display on a recorder is a most commendable technical achievement.

The paper by Fontaine on the "Explorator" equipment describes an attempt to break new ground by searching ahead for demersal fish, in addition this is an interesting sonar equipment for general fishing purposes.

The paper by Tucker and Welsby is important in that the equipment described is more advanced in design than any other civil sonar equipment. By utilising the principle of scanning in angle within one pulse duration, it becomes possible to increase the information per transmitted pulse many times. This experimental equipment seems to provide the only means available for determining the speed and direction of targets. It has many research applications and promises to provide a basis for a future commercial sonar.

Finally, I summarise by saying that the major advances have been in tactical handling, that some interesting new equipment is appearing, and suggest (along with Alverson and Wilimovsky) that we should face the future with minds very wide open to technical possibilities that seem to exist on a very wide front.

Mr. Mross (Germany): The paper on sector scanning sonar by Tucker and Welsby represents a real advance in the problem of detecting fish on the bottom, from the scientific point of view, and Mr. Fontaine's paper also represents a practical attempt to overcome the shortcomings in that field. There was no simple formula for the horizontal detection of scattered fish ahead. Definite training of fishermen was required to enable them to use sonar to advantage in respect of the presence ahead of herring, mackerel and pilchard. Future trawling might be carried out at depths of 800 to 1,000 ft and echo sounders using ultra-sonic intensity such as was described by Ellis, Hopkins and Haslett for deep-sea work represented an advance. His own firm had installed a special echo sounder for deep sea research on the new German research vessel. High frequency sounders as proposed by the Japanese were interesting and he agreed with their arguments, but the maximum depth at which they could give results was about 100 m. The well-known German netzsonde system allowed continuous study of fish behaviour. This was one of its main advantages. Intensive work had been carried out to develop the cable which represented the best compromise between the different electrical and handling requirements. The solution was a co-axial cable with a steel core well insulated. He personally had been surprised at the very good results obtained with this cable in various countries. It was very necessary to have an unobstructed run for the cable and this could easily be arranged on sterntrawlers. One problem in handling the gear was the strangeness of the equipment over the first three days to the crew. Once they were familiar with it, however, the system did give valuable information even in heavy weather.

Dr. Schärfe (Germany): In order to avoid misunderstanding I would like to point out that netzsonde is not a German invention. This system was mentioned at the first Gear Congress as having been experimented with by Lowestoft scientists in co-operation with the Pye organisation. The German echo-sounding companies, however, had certainly achieved the final success in working out this netzsonde telemeter technique and applying it to commercial fishing.

Mr. J. Fontaine (France): The Explorator equipment has been installed on the British trawler *D. B. Finn*, and I would like to give results of its use. It was installed early November, 1962, but there were initial difficulties and tests could only be started in January, 1963. This vessel makes voyages of from 19 to 20 days' duration, and after its last voyage it was publicly stated that for the fifth consecutive time it had landed a catch exceeding £10,000 in value. He had discussed the position with the skipper and the skipper had said that during February he had been fishing off the Norwegian shore and his catches were 50 per cent higher than those of his colleagues, and that over a period of a month he could credit to the operation of the Explorator equipment at least 10 per cent of the total catches obtained. The equipment had been developed specifically to meet the requirements of skippers. They could never find two skippers who were of the same opinion, and a detailed survey had to be made before they could really find out what were the operating characteristics needed. The conclusion they reached was that although the Boulogne skippers were interested in midwater trawling there was yet a real feeling that bottom trawling would continue for a long time. The skippers wanted to know where shoals of fish were and whether they could be caught with a trawl or not. They wanted to know whether the school was swimming close to the sea bed, and so they had to find an equipment which could distinguish between echoes from the school and any from the sea bed. The skippers wanted the recordings to be read very easily like those from a normal sounder. So they had to adopt the special recording techniques and introduce a computer which calculated the distance from the sea bed and from the shoal in terms of depth. Other information which the fishermen wanted was whether the school was going this way or that, and the Explorator provided for this too. It was not a scientist's equipment but a practical equipment developed to meet the needs of the working skipper. The working skipper had no special interest in science. All he wanted was results. Obviously, like other simple pieces of equipment, it was rather complicated in its circuits. On the other hand the set was built into boats which took

rather long voyages, and so it had to be sturdy and easy to maintain. Instead of a normal projector they gave it an elliptical shape so that in the vertical plane the beam is as narrow as possible so that they could separate the shoals of fish from other items on the sea bed. It was also necessary when the shoal had been detected to change from automatic scanning to manual control over a narrow sector. To test it out the laboratory had to fit it into a boat and a boat was lent them for some actual operating tests. They installed it on the bridge, but when they wanted to get it back from the skipper he wouldn't let them have it because he found it useful. So they actually had to send technicians down to the boat to measure it in order to develop a new prototype. Another machine was installed in another boat, and although the skipper understood quite clearly how it should operate, he operated it in a different way and got good results. The two skippers then compared results and found that although they differed they had both got good results. The skippers evolved their own technique in accordance with the results they obtained.

Mr. R. Lenier (France): In electronics considerable advances had been made throughout the world but they always applied those advances for strictly economic reasons in order to bring them into line with practical possibilities. In the French industry they endeavoured to provide the fishing boats with the best facilities taking into account all the realities of the case. He was privileged in having two allegiances because he was a half-time technician and a half-time fisherman, having spent many years fishing round Newfoundland. He was thus able to compare the differences of techniques as they had developed. While congratulating all the international industries on their progress he felt that so far as applications were concerned they should operate on the principle of more haste less speed.

Mr. Craig: Training is essential in respect of all aspects of fish-finding techniques. You can have formal training by instruction or use, and whole techniques of fishing may alter with the introduction of new fish-finding equipment so that equipment and the methods of fishing developed together. It is frequently some time after the introduction of an equipment before everybody is able to use it to the best advantage. Paper recording was of the highest value in echo sounding and in sonar. Other methods had their value, but recording continued to be the principal method of displaying information. This was clearly because of its integrating properties, and because it did not require anybody to be tied to the machine.

He emphasised the great difficulty of detecting fish close to the sea bed. In part, this was because the bottom was not a flat surface but more or less irregular. When fish were one or two feet off the bottom, their echoes might be confused with those of rocks. When sonar or any sort of horizontal equipment was used they must obviously use a comparatively narrow beam. And he showed by blackboard demonstration the difficulties when such beams were directed at an angle to the sea bottom. It was difficult to detect fish in the centre of the beam against reflections from perhaps 50 m × 50 m of sea bed. Fontaine had said this could be done, and they must agree that it could be done, but he thought it could only be done when the fish were very heavily concentrated indeed.

Dr. R. W. G. Haslett (U.K.): I would like to comment on Shishkova's paper on the study of acoustical characteristics of fish. This paper gives very many useful pieces of information regarding the assessment of signals from large shoals of fish and single individual fish. This is very important in assessing the size of fish shoals and likely catch. It would be very interesting if more information had been given about the technique for making these measurements of shoals because measuring at sea is very difficult to do with accuracy because of the variations in the position and the aspect of the fish. It is somewhat easier to make measurements by using the scale model technique, in which case you had to have carefully controlled conditions, and you must use the scale factor of 50 : 1 down, in which case small fish may be used. it is then possible to investigate the individual effect of interference between various factors. The results given in this paper must be taken as an average, and probably are very useful under practical seagoing conditions. When these properties are investigated in small-scale model techniques, however, great complications of signal strength versus fish length are found. In Fig. 2a in the paper an average has presumably been taken disregarding the interference effects which may be found in detail. The signal reflected by fish depends very greatly on the size of the fish in relation to the wave length of the acoustic sound. In the case of bottom trawling it may be that individual fish have to be detected as compared with midwater trawling where there may be large shoals to be detected. This explains the concentration for bottom trawling on individual fish echoes and the use of the cathode ray beam types of recorder displays which are locked to the sea bed thus enabling a larger amount of expansion and observation of individual echoes. In one trawling experiment, over a two-hour period on a single day, it had been found that on an average one fish was passed over every 10 yards, and that meant you had one fish every 10 yards over the volume of 60 ft wide by 8 ft high multiplied by the length of 8 miles. Figs. 3 and 4 of the paper indicated that it was hoped that the combination of the rather theoretical observations of fish echoes with the measurement of the signal strength and the size of the echoes from these displays may eventually lead to new designs of equipment which will be of benefit in assessing the size of the catch and the size of individual fish.

Dr. D. H. Cushing (U.K.): demonstrated on the blackboard the information that Dr. Haslett sought in connection with the Russian paper by sketching the results of certain tests. Some were made on perch in a small tank, some on cod and herring in the dock at Lowestoft, and others were made in Norwegian fjords. Some fish were rigidly suspended and some not, but in both methods maximum signals were taken, and they showed a clear relationship between signal strength and the length of the fish. That was the basic information that was required in order to analyse fish schools. The measurements had been rather difficult and complicated to secure for physical reasons but from data of this kind they could go on to make analyses of the signal strength of fish schools and eventually, one hoped, be able to count the fish.

Mr. P. G. Schmidt (U.S.A.): The use of aeroplanes has been left out in the treatment of fish detection. The tuna, the sardine industry and the menhaden people on the east coast of U.S.A. all make extensive use of aeroplanes for locating fish. We are working off the north of Chile where conditions are somewhat similar to those in Peru. During last year we used aeroplanes more and more, both in long-range and close-range activities, to support our operations in locating and actually setting the boats on the fish. At the same time a considerable quantity of echo-sounder equipment has come into use and about 100 per cent of the boats have some echo-sounder equipment. About 30 or more asdic type

units have been installed. But we have found that we would prefer to spend on aeroplanes the 15 cents a ton that it is estimated is the cost of operating one aeroplane to every 10 boats, rather than go into the asdic type of echo sounder.

When we started the survey we used Chilean operators or pilots who had no previous experience, and we thought anybody could learn the art of estimating the quantity of fish and helping the boats. We had a very good pilot, and after three or four months he had the confidence of the factories that employed him, and also had obtained the confidence of the captains.

About February, 1963, we brought down a foremost fish-spotting pilot from the menhaden grounds, and in a very few weeks' time the whole industry found that fish spotting was a science. This man, in a few days, showed us that we knew nothing about the subject, and that he could successfully estimate, within a very few tons, the fish in large shoals and could actually set the boats onto the fish far better than the fish captains.

From this experience all operators are now going further into the aeroplane spotting business at the expense of the asdic type of echo sounders. There are two types of spotting—long-range spotting to determine where the fish may lie, and, secondly, after bringing the boats there, staying with the shoal and actually setting the boats on the fish. In a way the captains resented this because they felt they were being replaced by one who was not a fisherman. But after a while they depended more and more upon the man, and when he is not flying they almost feel helpless.

It was interesting to see this evolution. Fish captains did not necessarily make good aeroplane spotters. It took an intensive training for years and actual experience to determine how to set the nets and estimate the wind and currents, etc. from the aeroplanes. It would be interesting if, in future publications of the FAO, some more information could be made available on this subject because they looked at this now as an extension of their fleet. They looked at the aeroplanes as if they were buying another boat. It is just as complicated to select an aeroplane and to pilot an aeroplane, and to develop the pilot's side of the business, as to develop a captain and the fishing operation itself. In the menhaden industry of the U.S.A. they had used aeroplanes extensively for over 10 years and they were now employed at the ratio of about one aeroplane for about every 10 boats.

Dr. Cole (U.K.): We are in some doubt as to whether Mr. Fontaine with his apparatus can, in fact, detect fish very close to the sea bottom. Mr. Craig referred to the interference between bottom echoes and the echoes of fish very close to the sea floor, and, having regard to the fact that the headline of the trawl is only 2 or 3 m above the sea bed, we really doubt whether the skippers can actually see the fish close to the bottom. We are wondering whether skipper Warham was in fact seeing the fish that he took. Might he not be seeing fish that were somewhat higher above the sea bottom and was inferring from those and, successfully inferring, that there were also fish in close proximity to the sea bottom, and within the level that he was actually fishing with his trawl?

Mr. Fontaine gave his answer in the form of a demonstration on the blackboard aimed at showing how the energy emitted by the Explorator device was directed towards the bottom of the sea ahead of the ship. That beam could be directed towards the sea bed at an angle of approximately 30 deg. but that was variable and the opening of the beam could be plus or minus two deg. Only a small portion of the energy reaching the sea bed would be reflected back to the receiver; the greater part would be reflected upward and away from the ship like light striking a mirror. A school of fish would return greater energy to the receiver than the sea bottom so that they got back echoes in a relatively thick trace. The sea bottom would come out in a greyish form on the recorder, but the fish trace would come out darker. The trace of the school of fish would eat into the trace of the sea bed which showed that the fish were very close to the sea bed. Slides reproduced in his paper showed some of these schools which came up precisely in that way. Skipper Warham of the *D. B. Finn* had carried out this system, and on seeing the traces had had the inspiration to deduce the presence of a large school of fish. He really did a marvellous piece of fishing over a two-day period.

Mr. V. Valdez (Peru): In Peru our big fleet of 1,000 fishing vessels has only one-fifth of its number using echo sounders. They operated along the coast and ventured sometimes 20 or 30 miles offshore only in spring and in autumn. In summer they have a difficult problem because the fish are too close to the surface, and as the boats progressed they cut into the shoals and cannot get traces on their recorders. They have tried to overcome this by means of asdic, and in that way completed their echo survey. In general, however, the fishing was so good that the men did not need overmuch help in getting more fish. Lately, however, with the high concentration of fishing boats it was becoming necessary to find some new areas for fishing. When working close to the coast it was difficult sometimes for the fisherman to get good catches, and when the fish were far from the coast the fisherman could not get there because he did not have the skill or training to go those distances. The problem was how to locate the schools and tell the fishermen where the schools were. He wanted to find a transducer that would locate the fish in summer and avoid splitting the schools.

Mr. V. G. Welsby (U.K.): I would like to add a few remarks to the paper presented by Prof. Tucker and myself. Two of these points arise from what we have heard about the Explorator. One thing is that although we discussed rapid electronic sector scanning, that is scanning of a complete sector within one pulse, it is worth remembering that electronic scanning technique can be used for slow scanning at any speed you like, and this provides us with a very convenient method of doing something much the same as slow mechanical scanning and of doing it by electronic means with a transducer which is fixed, thereby removing the necessity for heavy, expensive, complicated devices to move the transducer.

The other point is that which has been just discussed. If indeed the reflection from the bottom of the sea is of the very low level suggested, then I suggest that this shows very clearly that the technique which we have put forward in our paper of rapidly scanning a narrow sonar beam will definitely work, because if, in fact, the back scatter from the bottom is sufficiently low in level to allow this relatively wide beam with its four deg beam angle to operate, then the system which we have suggested of using a considerably narrower beam, ought to work even better. That will be seen in the future.

My last point is that although in our paper we have talked about the possibility of using electronic sector scanning—looking forward from the ship to see fish near the bottom—of course, this is not the only possible use. It can be used to look astern or, in midwater trawling, to enable an immediate continuous picture of the fish shoal to be seen during the actual catching of the fish, and the net, too, can be watched and its movement as well as the fish school itself.

Mr. Halliday (U.K.): I rather agree with Dr. Cole in doubting the ability of the Explorator to detect fish very close to the bottom unless the fish happens to be there in very large schools. I think Dr. Haslett mentioned earlier our experience in that what is regarded as good commercial fishing is fishing where the fish very often occur singly and have to be detected singly. We carried out some experiments quite recently with the object of finding out how the reflection coefficient of the bottom does in fact change with the angle. This was done with a very simple apparatus which consisted of a transducer with a fan-shaped beam, the wide angle being in the vertical plane, and very short pulse. By this method we hoped to show that as the sound progresses farther, obviously the angle at which it is arriving at the bottom becomes more and more acute, and that at some particular distance the echo-strength would fall sufficiently to allow fish to be detected against the bottom echo. But although the experiments are very preliminary we did not find any trace of fish echo occurring at the same time as the bottom echo.

In connection with Shishkova's paper it might be of interest to mention a fact which we have noticed which shows the difference between vertical sounding of strong schools and horizontal sonar fish detection. It is, of course, well known that with vertical sounding the echo from the shoal is very much drawn out and can give a false impression—and this is really what one might expect if one considers that the sound probably reverberates in the school from fish to fish. This would obviously give the effect of a drawn-out echo, but, curiously enough, in sonar work on pelagic schools this does not seem to occur. In other words the traces of the recorder are quite sharp at the farther edge. I cannot explain this and, so far, we are content to make use of it, because obviously it is a very neat way of measuring the extent of the shoal in range.

Mr. Lusyne (FAO): No answer has been given to Mr. Valdez's question about a transducer which will enable him to pick up schools on the surface and avoid splitting them. I can, however, relate some experiments which were carried out on the Sandettie grounds on spent herring last year by the Belgians. They had noticed that whereas a school of fish was clearly visible on the recorder they caught none. They tried to ascertain why the fish had disappeared. They towed a transducer astern and they noticed that the school seen on the ship's transducer was not picked up by the towed transducer; this indicated that the school had in fact disappeared. They conducted these experiments again on the North-West Rough, and in the same depth. The result was different. The fish schools picked up on the ship's transducer were found on the towed transducer. They also noticed that in fishing at a depth of 50 to 60 fathoms this disappearance of the school did not happen. They have so far concluded—and this applies particularly to spent herring—that the disappearance only happens in up to 25 fathoms of water. The experiments have been few but they do suggest something. A second indication is that there is a vast difference between the movements of the schools. In the sprat season on the French Coast the same method was applied, but they found there that every single school picked up from the ship's transducer was also picked up on the towed recorder.

Mr. Alverson (U.S.A.): asked if Mr. Fontaine could put into units of measure the terms "close" and "very close" as they related to the sea bed.

Mr. J. Fontaine (France): I shall try to give a clear reply to Mr. Alverson's question. Everything depends on the beam angle of the projector. With a normal sounder the beam angle is in the region of 25 deg to 30 deg and the power of definition is not great. Our purpose with the Explorator is to locate fish shoals some distance ahead of the ship. To do that we have been using not a normal transmission beam but one in which the narrow angle of opening is in the vertical plane. It is the angle in this plane which determines the power of definition in depth, since it is the vertical distribution of fish that we want. Accordingly we have brought the vertical half-angle down to two deg, more or less giving a total angle of opening of four deg. This is a compromise between the angle of the beam, the size of the transducer, the ultrasonic frequency and the rolling and pitching of the ship. If a fish shoal, having a thickness of about 5 m to 10 m and a normal density, is on the ground, its echo will be partly confused by the trace of the sea bed, but as it reflects a greater energy it gives a darker trace in the greyish one of the sea bed. It will be for the skipper, from his experience, to deduce whether that darker trace is a fish shoal, a wreck or a rock.

Mr. Craig, summing up, said many useful points had been brought out very clearly. One that should be emphasised very strongly was that the detection of fish schools on the bottom was very difficult. There seemed to be some division of opinion about the amount of echo that would be returned from the sea bed at various angles. This directly concerned this particular problem. Papers published by the National Institute of Oceanography describing the use of narrow beam sonar in surveys of sea bed made it clear that signals that came at an angle from the sea bed were very different, depending on the nature of the bottom. They were, in fact, so different that the bottom could be quite adequately charted by the use of narrow beamed sonar. He thought the nearest to a simple summing up of this problem was that given by Mr. Halliday; namely, that on smooth sea beds when dealing with fish in considerable shoals it was very likely that sonar impinging at a narrow angle would show the fish up. If conditions were not so good it was not easy to see the fish unless they were fairly well clear of the bottom. That was his feeling from all the different points of view expressed—namely, that when conditions were good this detection could be quite possible, but when conditions were bad it would be very difficult indeed.

Another point was that made by Dr. Welsby that the scanning technique described by him had a number of applications quite apart from direct fish finding. It could be used to look at the trawl, to look at the behaviour of the fish in relation to the trawl. This point had much appeal. But the difficulties were very similar to that of handling the netzsonde. Cables would have to be provided and transducers would have to be put in the right place—possibly on the bottom of the ship. Another point of value was the importance of searching for fish by vessels other than fishing research vessels. In some fisheries where ships are not adequately equipped this was necessary—and that was in fact the start of fisheries sonar. Norwegian research vessels searched for the schools and directed the fishing fleet.

As regards aeroplanes their use had, in fact, been covered at the last gear Congress by a fairly considerable paper, but certainly more information would be welcomed. It could only be provided by people describing the conditions in their own fisheries because only certain fisheries had the possibility of effective air search. Clearly the fish must be very close to the surface and they must be in compact schools. This was a method of great value in suitable areas.

Mr. Valdez (Peru): inquired if instead of aeroplanes

helicopters could be used for flying more slowly and detecting patches of plankton or possibly towing a transducer at slow speed in the water to detect the fish.

Mr. Alverson (U.S.A.): This is being done already very extensively by the military, but I do not think it is fish they are looking for!

Japanese Mothership and Fleet Operations for Salmon, Crab, Longlining, and Tuna

Abstract
This is a composite article, describing in five sections by different authors the organisation and operation of Japan's specialised fishing fleets, which began activities in this form in 1940 by trawling for flatfish and crab, but now take in other species such as cod, pollock, shrimp and halibut. In addition to these fleet operations covering trawling and purse seining, specialised craft and activities now cover salmon gillnetting, crab fishing, longlining and tuna longlining. The general composition and organisation of these fleets, together with the operational techniques that have been developed, are fully described, as well as the specialised gears that have been evolved for securing the best results. The motherships are attended by specific numbers of catchers in proportion to their size and needs, and are serviced by fuel and supply vessels, as well as reduction and transport craft. In the various sections are detailed the procedures through which the fleets work as units covering the assigned areas with maximum efficiency.

Les flottilles de chalutiers Japonais travaillant avec un bateau-mere: leurs methodes et leur equipement

Résumé
Cet exposé décrit en cinq sections rédigées par différents auteurs l'organisation et l'exploitation des flottilles Japonaises de pêche spécialisées, qui entreprirent ce type d'activité en 1940, par la pêche au chalut des poissons plats et des crabes, mais qui actuellement pêchent d'autres espèces telles que la morue, le colin, les crevettes et le flétan. Il faut ajouter à la flotte pêchant au chalut et à la senne tournante de nouveaux bateaux spécialisés pêchant le saumon au filet maillant, les crabes, et pratiquant la pêche à la palangre du thon et d'autres scombridés. Les auteurs décrivent dans les détails la composition et l'organisation générale de ces flottilles, ainsi que les équipements spéciaux perfectionnés en vue d'obtenir les meilleurs résultats. Les bateaux-mères sont accompagnés d'un nombre donné de bateaux de pêche, proportionnel à leurs dimensions et à leurs exigences, et sont desservis par des unités auxiliaires assurant leur approvisionnement en combustible et en vivres, ainsi que par des unités de traitement et de transport. Les différentes sections décrivent dans les détails les opérations effectuées par les flottilles dans les zones de pêche qui leur sont assignées, qu'elles exploitent avec le maximum d'efficacité.

Flotillas de arrastreros Japoneses que trabajan con un buque madre; sus metodos y equipo

Extracto
Esta ponencia describe en cinco secciones escritas por varios autores, la organización y explotación de las flotas pesqueras especializadas del Japón, que iniciaron esta clase de actividad en 1940 pescando al arrastre peces planos y cangrejos de mar y que actualmente también capturan especies como bacalao, abadejo, camarón e hipogloso. A las flotillas dedicadas a la pesca al arrastre y al cerco, hay que añadir embarcaciones especializadas en la captura de salmón con redes de enmalle, cangrejos de mar y atún y otros escómbridos con palangres. Describen los autores con pormenores la composición y organización generales de estas flotillas y los equipos especiales que se han ido perfeccionando para obtener los mejores resultados. Los buques madre van acompañados de un número determinado de pesqueros, que está en proporción con sus dimensiones y necesidades y están atendidos de barcos de suministro (combustible, víveres, etc.), de reducción y de transporte. En las diversas secciones se describe el trabajo de conjunto de las flotillas, que explotan los caladeros que se les asignan con la máxima eficacia.

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Mothership Fleets, their Methods and Fishing Gear

JAPANESE mothership trawling operations started in 1940. World War II interrupted the operations but they were resumed afterwards, and have since grown year by year. At first, the catch was limited to certain species of flatfish and crabs but various fish-processing vessels are now being used.

The fishing grounds most favoured are found along the continental shelf at depths of 50 to 600 m, which stretches from Bristol Bay in the east as far as the Oliutorsk area in the west, or from Cape Oliutorsk as far as Unimak Island. The type of fish caught varies according to the depth fished and comprises species of flatfish (*Lepidopsetta mochigarei, Limanda aspera, Liopsetta obscura, Pleuronectes pallasi*), cod, Alaska pollock, sablefish, long-jawed rockfish, Pacific pink shrimp, halibut, arrow-toothed halibut, etc.

The type and number of catcher boats in a fleet are determined by the processing capacity of the mothership

and the individual fishing capacity of the catcher boats. A reduction ship normally uses 23-25 Danish seiners or a group composed of 18-20 bull trawlers, plus eight to ten Danish seiners. A shrimp cannery ship or a refrigerating ship has 10-12 bull trawlers or five to eight otter trawlers.

Fishing operations last for about five months, from the latter part of April to the latter part of September. During this season the sea and weather conditions are favourable. During the rest of the year, although fish are present in abundance, the sea is rough and the weather so bad that it is difficult for small vessels to fish.

Motherships

Reduction ships have a fish meal and oil plant as well as freezing equipment and Baader filleting machines. Besides fish meal and oil, they produce liver oil, salted cod, frozen fillets, etc.

Refrigerator ships produce mainly salted cod and frozen products of flatfish, sablefish and rockfish, etc. Shrimp cannery ships produce both canned and frozen shrimp or only canned shrimp.

Supply vessels provide the fleets with fuel oil, fresh water, provisions and fishing gear. The supply ships usually form a team and consist of 1,000 to 1,500 GT refrigerated ships for the transport of the frozen products and of 2,000 to 3,000 GT freighters for the transport of fish meal and canned shrimp.

Trawling operations

Two vessels of about 75 to 100 GT, 250 hp of identical design and engines, form a bull-trawling pair. In design these vessels are a compromise between the Japanese and European trawler types and have been developed over many years. The bridge is approximately amidships, leaving a free foredeck up to the forecastle. The mast carries no derrick but has a gilson for working the fishing gear. Two wire-reels are installed on either side just aft of the forecastle for reeling the warps. One warping head is provided on each side of the bridge for hauling the gear. At the stern, both to port and starboard, a roller is installed for leading the warps to the warping heads.

The engine is normally installed a little aft of midships. The vessels are fitted with the usual navigational instruments as well as with echo sounders, radar, Loran, direction finders and radio telephones.

The crew normally numbers 12 men. For general layout of a bull trawler see Fig. 1.

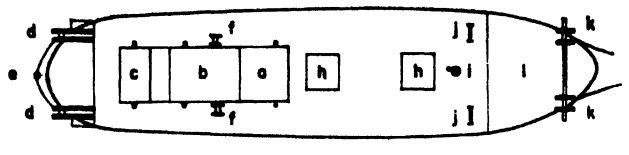


Fig. 1. Deck arrangement of bull trawler. (a) bridge, (b) engine room, (c) galley, (d) stern roller, (e) stopper, (f) warping head, (g) quarter roller, (h) hatch, (i) foremast, (j) wirereel, (k) bow roller, (l) forecastle.

Most Japanese Danish seiners are wooden vessels of 60 to 80 GT, powered by 250-270 hp engines. Deck arrangements (Fig. 2) and appliances are more or less the same as for the bull trawlers, except that the foredeck is comparatively smaller, leaving a larger working space aft. Crew numbers 18 usually.

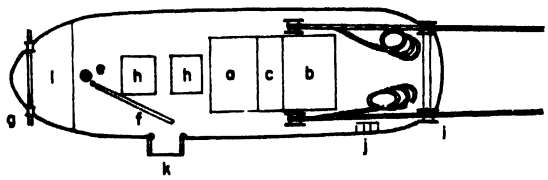


Fig. 2. Deck arrangement of Danish seiner. (a) bridge, (b) galley, (c) engine room, (d) warping head, (e) foremast, (f) derrick, (g) bow roller, (h) hatch, (i) stern roller, (j) buoy, (k) gangway, (l) forecastle.

Fishing gear and methods

Design of bull trawlnets is mainly based on that of the otter trawl. For details of net construction see Fig. 3 for shrimp and Fig. 4 for flatfish. The sweepline is made of a combination rope, 45 mm diameter, 200-250 m long, for operations at depths of 80-100 m. The warp is usually 17-18 mm diameter wire, 400-500 m long and is used at depths of 80-100 m. To keep the warps close to the bottom, a length of chain is sometimes inserted between the warp proper and the combination sweepline. The net is constructed of polyethylene twine (400 denier filaments), or of 'Kuralon' twine (20's yarn). (In Figures 3 and 4 for upper bony read bating).

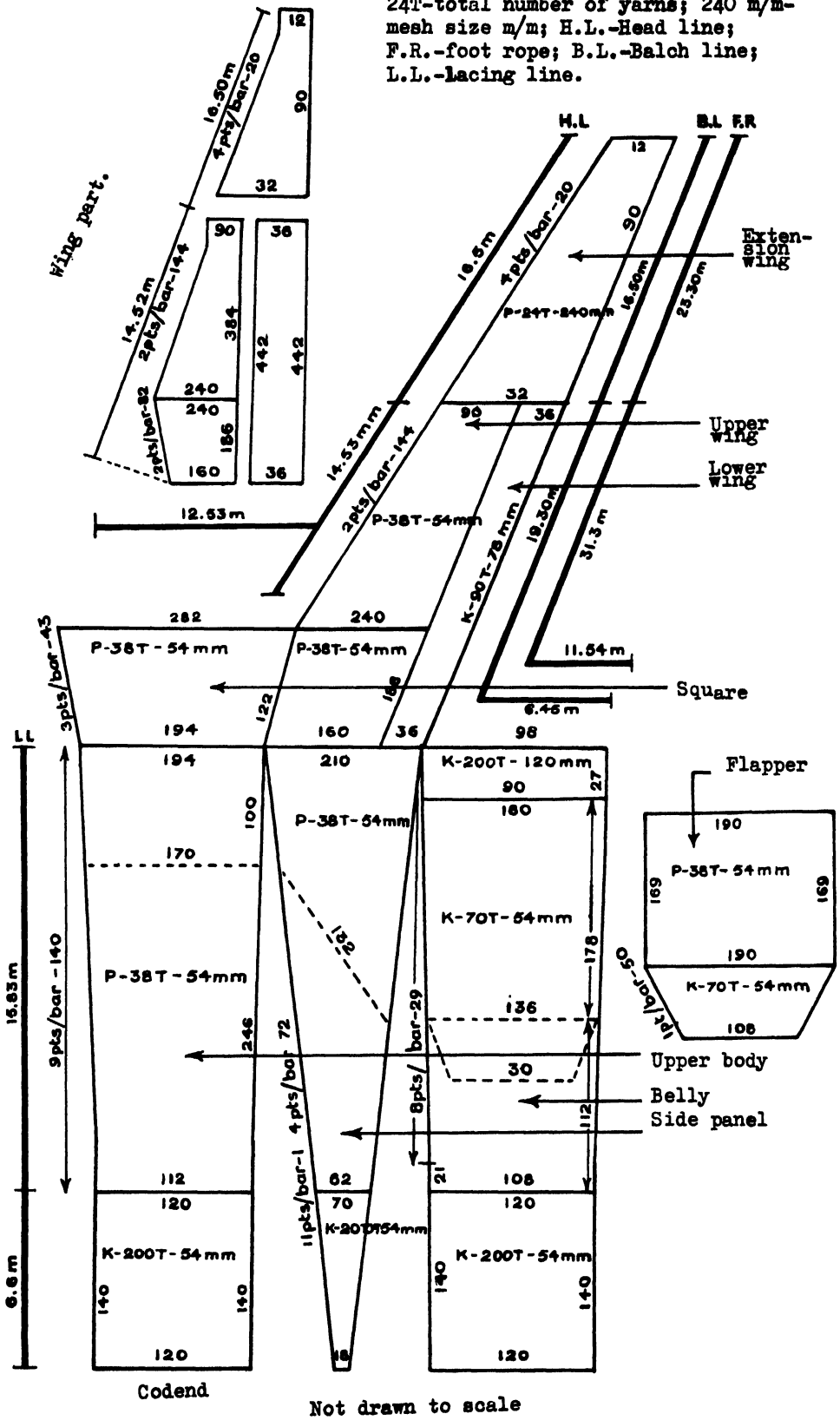
In shooting the gear both vessels take up position at about 60° on opposite sides of the towing course. The net boat, with the gear stacked ready for shooting, takes over from the other boat the warp-end which is fastened to the butterfly of the aftmost wing. The net is then shot over the stern and, when both wings are in the water, both ships steam out on opposite courses until the sweeplines plus 200-300 m of warp have been payed out. The vessels then manoeuvre until they are about 400-500 m apart, set parallel courses and commence dragging. The general course is normally with wind and/or current and the tow varies from 15 to 80 min, depending on the catch.

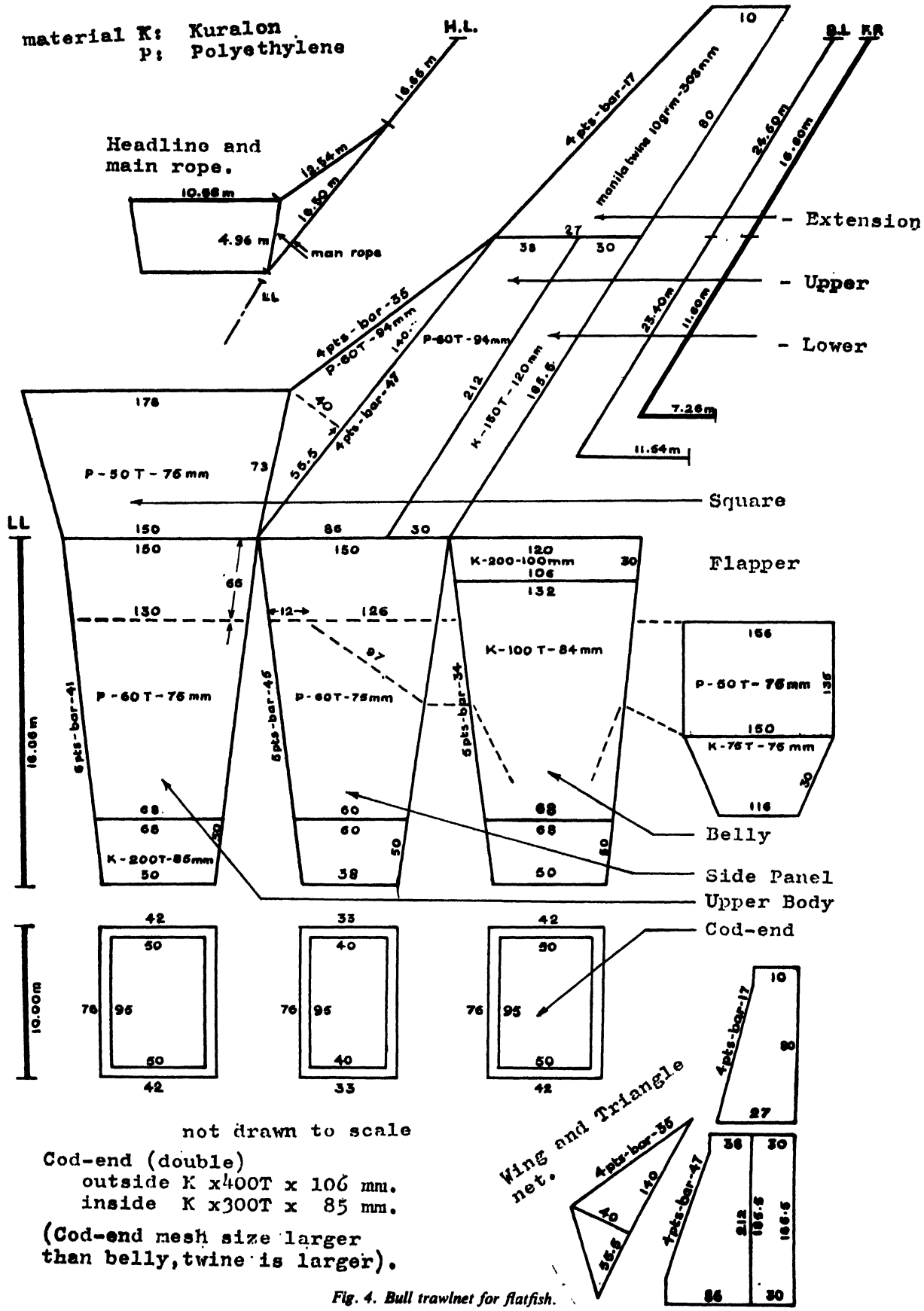
Operated by two vessels, the net obtains a larger opening than the otter trawl which is a main advantage of bull trawling. (Fig. 5.)

To haul, the two vessels converge and begin hauling so that by the time the sweeplines come in they are close enough for the net boat to take over the sweepline from the other boat. The warps are hauled in over the warping heads and wound on to the reels forward. The combination ropes are coiled on the foredeck ready for shooting again. As soon as the danlenos reach the rollers on the stern the one wing is brought round to the bow and the net is further hauled on the side.

Specifications of the gear used by the Danish seiners is given in Fig. 6. The seine warps are of manila rope, 27-36 mm diameter, and made up of 12 to 13 coils for fishing at depths of 300-600 m, or seven to eight coils if the depth is less than 200 m.

Fig. 3 BULL TRAWL NET FOR SHRIMP
Note: K-Kuralon; P-Polyethylene; 24T-total number of yarns; 240 m/m-mesh size m/m; H.L.-Head line; F.R.-foot rope; B.L.-Balch line; L.L.-Lacing line.





not drawn to scale

Cod-end (double)
outside K x400T x 106 mm.
inside K x300T x 85 mm.

(Cod-end mesh size larger than belly, twine is larger).

Fig. 4. Bull trawlnet for flatfish.

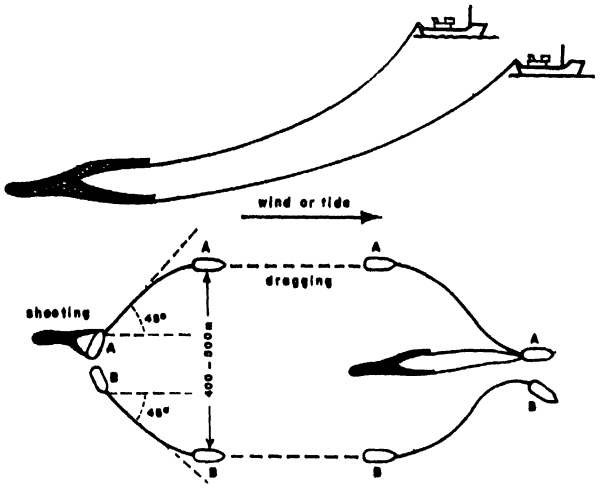


Fig. 5. Outline of bull trawling operation.

Trans-shipment

With Danish seines the catch is taken on board and stowed in the hold. Before trans-shipment, about 10 tons of fish are packed in baskets which are suspended over the side and held by a strop which is fastened to the foot of the mast.

With bull trawlers and otter trawlers the codend is detached from the net as soon as the net is hauled in. The codend is then kept suspended over the side in the same way as in the Danish seiners.

In both cases the catcher boats approach to within about 30 m or 40 m of the mothership. Wire ropes are veered out from the mothership on to which are fastened the basket or codend. The catches are then hauled aboard the mothership. The connecting wire ropes between the mothership and catcher are normally handed over by a small boat called "Daihatsu", which also transfers

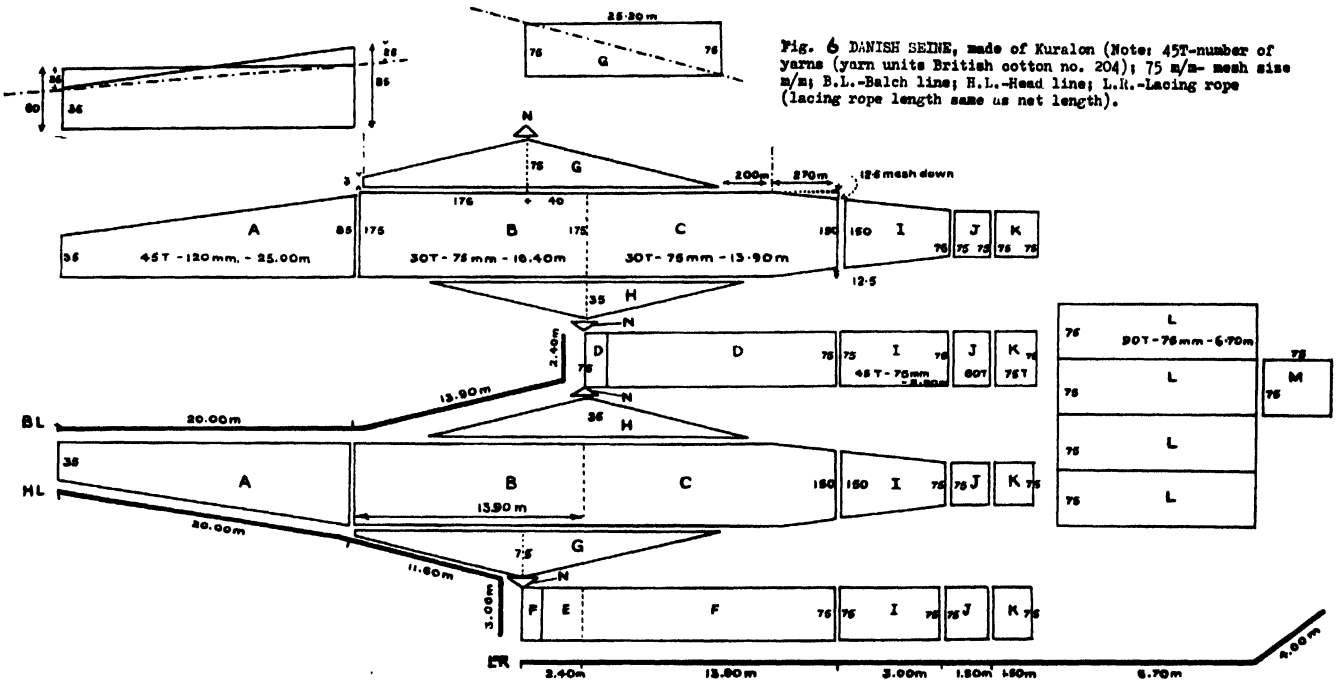


Fig. 6 DANISH SEINE, made of Kuralon (Note: 45T-number of yarns (yarn units British cotton no. 204); 75 m/m- mesh size m/m; B.L.-Balch line; H.L.-Head line; L.L.-Lacing rope (lacing rope length same as net length).

Specifications for Figure 6

Position	Name	Twine size	Mesh size mm	No. o mesh	Net length m	No. of piece	Reference
Extension wing	A	45	120	60	23·00	2	Flat Knot
Wing	B	30	75	175	16·40	2	,,
Side panel	C	30	75	175	13·90	2	,,
Belly	D_1	60	75	75	1·20	1	,,
Belly	D_2	30	75	75	15·45	1	,,
Square	E_1	45	75	100	0·40	1	,,
Square	E_2	30	75	75	2·40	1	,,
Baiting	F	30	75	75	13·90	1	,,
Triangular upper	G	30	75	75	25·20	1	,, Cut down
Triangular lower	H	30	75	35	15·60	1	,, Triangular 2
Lengthener							
Side panel	I_1	45	75	75	3·00	2	,,
Belly and baiting	I_2	45	75	110	3·00	2	,,
Lengthener	J	60	75	75	1·50	4	,,
Lengthener	K	75	75	75	1·50	4	,,
Codend	L	90	75	75	6·70	4	,,
Codend bottom	M	120	75	75	5·70	1	Sheet bend
Triangle net	N	45	75	10	0·75	2	Cut down Triangular Net 4

Specifications for Figure 6

Sinker & Float	Weight of one piece or Glass ball dia	Fitting pitch	Total
(Sinker) China bobbin			
Extension wing	190 gr	1 by 0·36 m	112
Wing	110 gr	1 by 0·18 m	160
Bosom	110 gr	1 by 2·40 m	20
(Float) Glass ball			
Extension wing	120 mm	1 by 1·00 m	40
Wing	150 mm	1 by 0·75 m	40
Bosom	150 mm	1 by 0·30 m	10

Composition Rope (Material: Manila)

Position		Size dia mm	length m
Extension wing	Headline	21 mm	20·00 × 2
	Balch line	28 mm	20·00 × 2
	Sinker line (Groundrope)	15 mm	20·00 × 2
Wing	Lacing rope	21 mm	11·20 × 2
	Headline	21 mm	11·60 × 2
	Balch line	21 mm	13·90 × 2
	Groundrope	15 mm	13·90 × 2
Codend	Lacing rope	21 mm	6·70 × 4
and Belly	Lacing rope	21 mm	6·00 × 4
and Baiting	Man rope	18 mm	4·00 × 2

fresh stores, etc. For refuelling the catchers go alongside the mothership.

For cannery ships, catcher boats normally go alongside the cannery mothership with careful manoeuvring. The mothership prepares beforehand the mooring ropes at bow and stern on her leeward side.

M. Neo

How the Salmon Fleets Operate

JAPANESE salmon mothership fleets operate in the waters around the Aleutian Islands and off the Kamchatka Peninsula.

Each mothership has 30 to 36 driftnetters as catchers. These driftnetters shoot their nets towards evening and retrieve them the next morning. On board the mothership catches are sorted by species and processed to canned, frozen or salted products. Wastes from the plants are reduced to meal and oil.

The fleets' home ports are in Hokkaido, the northernmost island of Japan. They attain their allocated catch quota in about 70 days from early May and return to their bases late July or early August.

In 1962, 11 motherships operated in the Northwest Pacific, with 369 driftnetters.

These catcher boats are steel or wooden boats of 75 to 85 GT, and are powered by 280 to 400 hp engines. They are manned by 20 to 22 crew members and equipped with nethaulers, either mechanically or hydraulically driven. Navigation instruments consist of radar, Loran, direction finder, compact gyro-compass and micro-wave radiophone.

A licence to engage in mothership fishery is given to applicants on joint applications by the owner of the mothership and the owners of the catchers to organise a fleet. The 11 motherships operated in 1962 are owned by eight different fishing companies. To keep mothership operations in order, an agreement is made between the eight owning companies. This is designed to co-ordinate activities and prevent crowding ; it divides the whole area into 169 districts, (longitudinally and latitudinally) each wide enough to accommodate about 40 driftnetters.

No mothership is permitted in more than one district at a time. The area of these districts varies slightly between east and west of the 170°25'E longitude or so-called "Bulganin Line", because of the regulations specified in the Annexe of the Russo-Japanese Convention. (Fig. 7.) The right to occupy any district is given

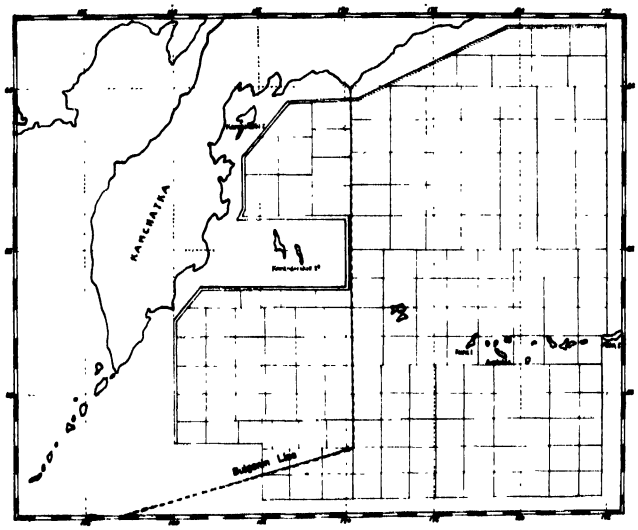


Fig. 7. Fishing area open to mothership operation.

to the fleet which first declares its intention to use it, prior to its entry. Once declared, that particular district is closed to fishing by, or passage of, other fleets. The fleet which intends to transfer to another district must announce its desire to leave its present district and to occupy a new district.

The daily fishing pattern of each fleet is decided by the mothership. This prepares each day a chart indicating the spots to set nets, and allocates one of these spots to each catcher boat at its option according to the order of its arrival for the delivery of catches. (Much of the success of fishing depends upon the ability of the staff of the mothership to determine the productive spots, because salmon are not distributed equally over the entire district.)

The fishing grounds of catcher boats are very often far away from the motherships, so that they may have

to go 50 miles in extreme cases. Catcher boats usually start shooting nets around 16.00 hrs and begin retrieving around 01.00 hrs next morning. By Government regulations they are required to deliver their catches aboard their mothership at least once every day.

When vessels find their catch is tapering off, they leave their territory and transfer to a more promising district. In deciding their destination, they depend upon the following information: (a) Catches of other fleets judged by daily catch reports, which are exchanged mutually. (b) Reports of scouting boats, of which it is permitted for each fleet to have three or four to prospect outside the territory, where other fleets are not operating. They can operate as many days as they want. (c) Past experience. The probable routes of the major salmon runs and the timing of their arrival at different districts can be more or less predicted from previous experience. This knowledge is also used by scouter boats.

Some fleets often occupy in advance a favourite district in order to forestall others.

Catcher boats and operation

To the east of the "Bulganin Line" a total length of net of 330 nets (15 km long) can be operated by each catcher boat, while to the west of the same line only 264 nets (12 km long) can be used. The mesh size of these nets must be 130 mm and 121 mm respectively; the total fleet of nets being made up of an equal number of nets of each mesh size. Before the Russo-Japanese Convention was concluded in 1956, three different mesh sizes were used; 118 mm, 121 mm and 124 mm. The 118 mesh size was suspended in 1960 and 130 mm mesh size was introduced to replace the 124 mm mesh size nets. Whereas the proportion of 130 mm mesh size nets was initially 25 per cent of the full number of nets to be used, this proportion was raised to 50 per cent in 1961. The change in the legal mesh size was designed to give the smaller fish a better chance to escape; however, some Japanese fishermen believe that 121 mm mesh is the most effective, both to prevent netted fish from dropping out and for gilling mature fish. For specifications of driftnets see Table I and Fig. 8a, b and c.

Table I.—Specifications of salmon driftnet (Mesh size: 130 mm)

Webbing
1. Main webbing
   Nylon multifilament 210d/15.
   Trawler knot 61 meshes deep and 700 meshes long.
2. Selvage strips and floatline and leadline.
   Nylon multifilament top or bottom half-mesh: 210d/15; second half-mesh: 210d/27; third half-mesh: 210d/45 (mesh size: 85 mm).
3. End selvage.
   Nylon multifilament.
   Half-mesh: 210d/39.
   Attached to the main web by 210/21 twine.

Ropes
1. Floatline.
   Polyethylene monofilament 400 d; 3 × 3 strands, and 13 gm. Stabilised.
   Total length: 51·90 m.
   Length of connecting ends: 0·45 m each.
   Length on net: 50·00 m.
2. Leadline.
   Manila hemp, 2 × 3 strands, 45 gm, and treated with 'Life' dye.
   Coil proof.
   Total length: 50·84 m.
   Length of connecting ends: 0·42 m each.
   Length on net: 50·00 m.

Floats
55 floats, each with 225 g of buoyancy; of synthetic rubber.

Leads
57 pieces of lead, each weighing 75 g.

Hanging Materials
To fasten floats to floatline: 'Kremona' twine (20 S, 3 × 45).
To fasten leads to leadline: Spun nylon twine (6 S, 3 × 6).
To hang web to floatline: 'Kremona' twine (20 S, 3 × 27).
To hang web to leadline: 55 pieces of spun nylon twine (3 × 24), each measuring 2·42 m and folded in two.
To connect webs: 'Kremona' twine (20 S, 3 × 54).

Hanging-in ratio
91 m stretched webbing hung to 50 m line.

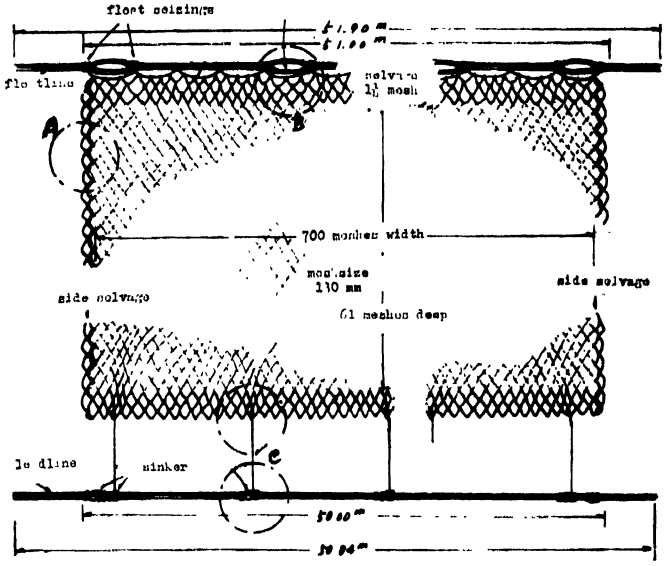


Fig. 8a. Construction of drift nets.

Most driftnets now in use are of nylon multifilament, but 'Teteron' (polyester) nets are also in use. Nylon monofilament nets have been found to be very efficient but, because of the higher cost and technical difficulties involved in handling, their use is limited to about 50 to 100 nets per boat. They are interspaced among the multifilament nets so that the fish are led to the more or less transparent monofilament nets.

Auxiliary gear

Each catcher boat is fitted out with a nethauler (Fig. 9) installed on the port side near the bow. In hauling, only the leadline, which carries most of the weight is pulled in by the nethauler while the floatline and the loose net are hauled in by hand. The haulers are mechanically or hydraulically driven and the hauling speed ranges from 50 to 70 nets per hour.

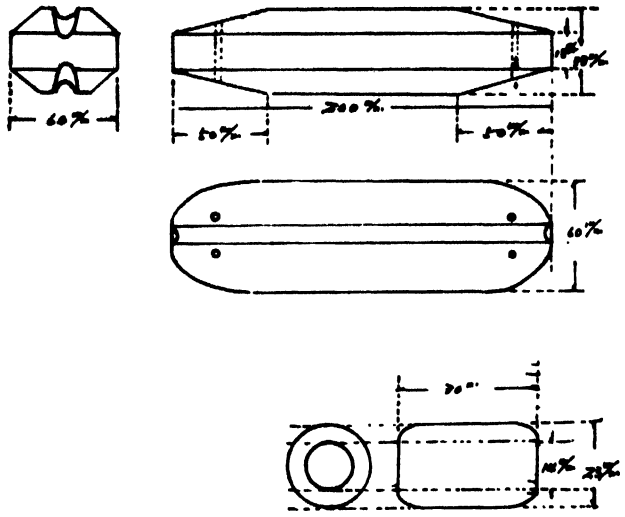


Fig. 8b. Construction of float and sinker. Float: *Material: synthetic rubber. Main dimensions, depth 38 mm, width 60 mm, length 200 mm. Volume: 297 cc, Weight: 67 gr, Buoyancy: 234 gr.* Sinker: *Material: lead, Main dimensions, length 30 mm, inside dia. 14 mm, outside dia. 23 mm. Weight 75 gr.*

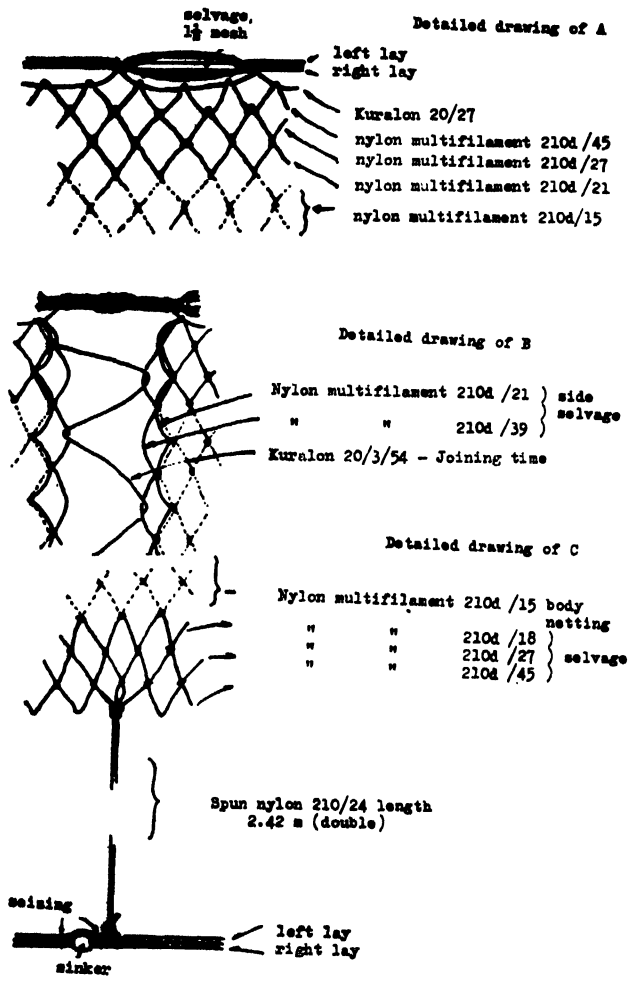


Fig. 8c. Construction of driftnets, detailed drawings of sections marked A, B, and C in figure 8a.

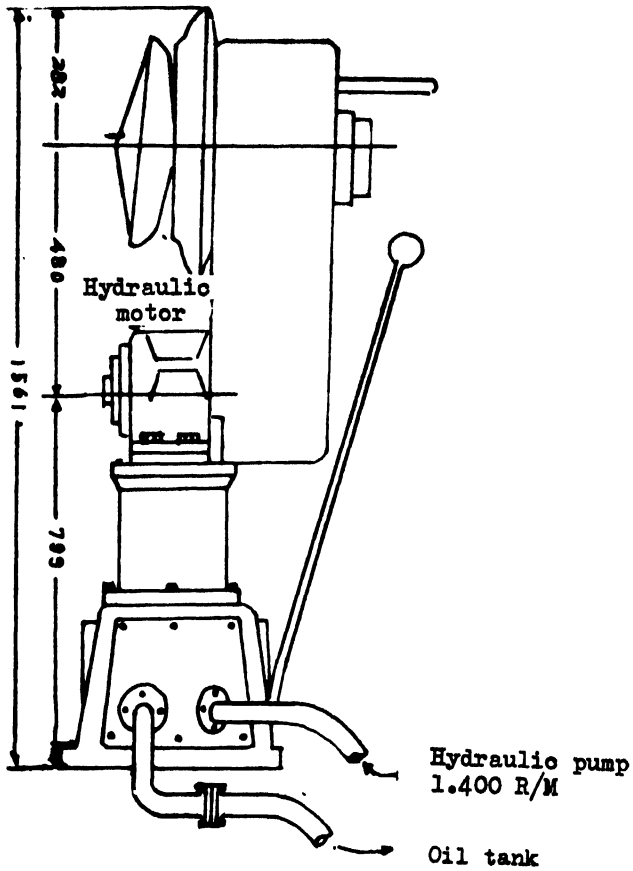


Fig. 9. Nethauler.

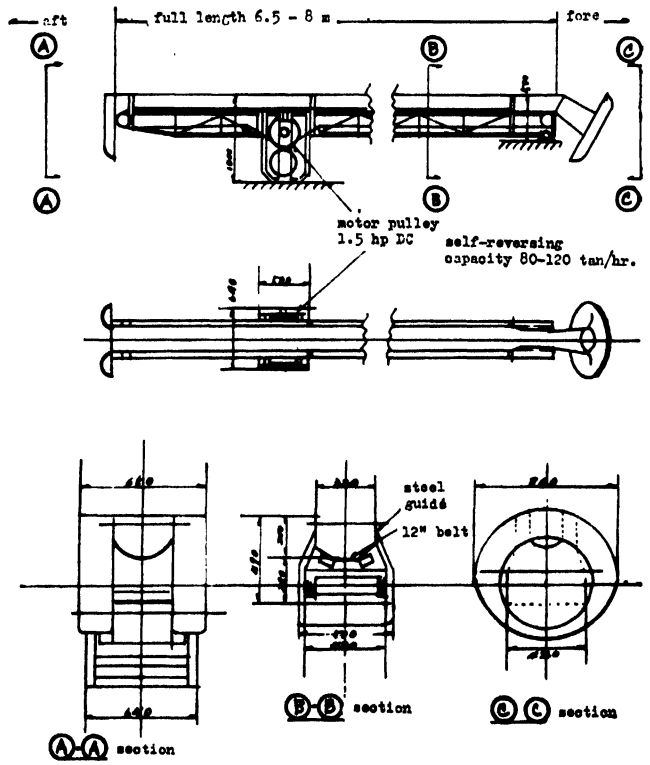


Fig. 10. Net conveyor.

There is a net conveyor on the starboard side to facilitate moving nets from the foredeck to the stern, where they are stacked ready for the next shooting. These belt conveyors are mechanically or hydraulically driven (see Fig. 10).

Although each catcher vessel has an echo sounder, little use is made of it in fishing since regulations prohibit the fleet from fishing while moving to new areas.

Operation

The best time to set the nets is immediately before dark. Boats arriving early usually wait for sunset before shooting their gear.

When the nets are set much before sunset the current adversely affects the shape of the nets, while if the nets are set after sunset the best fishing time is lost. In both cases, the catch efficiency of the nets decreases. In shooting, all the nets of each boat are set in one direction. This is partly to facilitate observation of the regulations regarding the total length of nets allowed per boat, as well as the minimum distance between adjacent fleets of nets. The direction of the set varies according to the area and season and it is determined in such a way as will best intercept the run of salmon under normal sea conditions. When the wind exceeds seven to eight m per second the nets are shot into the wind irrespective of the direction of the salmon migration.

During shooting, the nets are led over the roller on the stern (Fig. 11), while the boat has a speed of around six knots. The roller tapers towards the ends.

Fig. 11. Setting the net using net roller.

To facilitate location of nets, radio buoys and light buoys are attached to both ends (Fig. 12). They assist in revealing the general direction of drift as well as in recovering lost nets.

Hauling normally starts about 01.00 hrs. The boat is placed so that the nets come in on the port bow while moving dead slow ahead into the wind. The nethauler pulls on the leadline while the other parts of the net are hand-hauled by the fishermen (Fig. 13). After the nets are cleared of fish they are conveyed to the stern by the net conveyor.

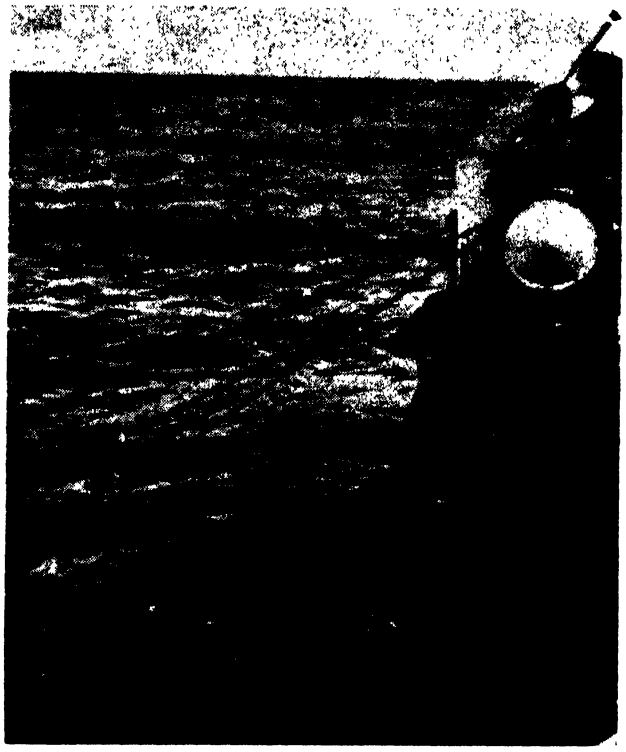


Fig. 13. Hauling the net, using the nethauler.

Transfer of catches

While catcher boats are out fishing, the mothership drifts around the area with current and wind but is careful not to interfere with the fishing operations. The exact position of the mothership and catcher boats is always determined on board the mothership and communicated to the catcher boats. Early each morning the mothership moves to the point where it is most convenient to receive catches. The new position of the mothership is communicated to the catcher boats in exchange for the latter's catch reports. Catcher boats, after they have completed hauling their nets, return to the mothership by a direction finder bearing.

Three Methods Used in Catching Crab

by Nippon Suisan Kaisha Ltd.

IN fleet operations the crabs sought are the schools moving inshore during spawning migration (chiefly representing vertical movement) from April through May, and during feeding migration (chiefly representing horizontal movement) from late July through autumn. The search for schools of crab is conducted according

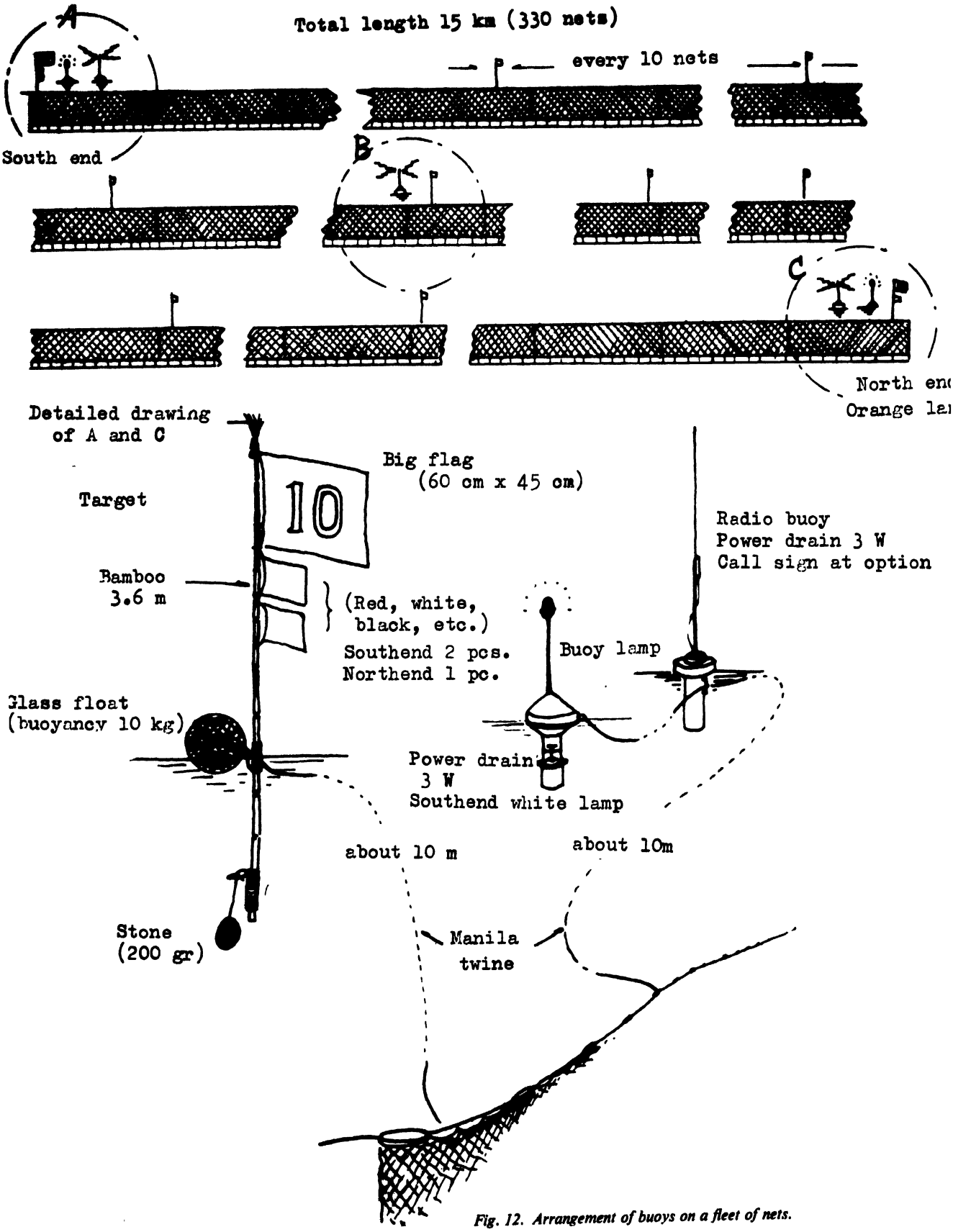


Fig. 12. Arrangement of buoys on a fleet of nets.

to plans mapped out on the basis of such factors as the special characteristics of the waters involved, season, depth of sea, water temperature, etc. Such surveys are usually conducted at depths of 50-150 m in the Bristol Bay area, and in the fishing grounds off West Kamchatka; but Soviet factoryships operate closer inshore. The method is to lay short strips of nets at one to three-mile intervals and check at 12-24-hour spells.

In such surveys, watch is kept on the following points: (a) distribution of bottom temperature, (b) composition of currents and tide; (c) depth of water; (d) composition of school; (e) size of school; (f) composition of legal-size crabs; (g) quality of legal-size crabs.

Fishing equipment and method

There are three kinds of crab fishing equipment: (a) bottom gillnets, or rather tanglenets; (b) trawlnets and (c) crab pots. Trawling was used on the fishing grounds of Bristol Bay during 1953/54 but has since been abandoned because of the low yield resulting from the intrusion of fine-grained sand in the shoulder-meat of the crabs caught by this method. In Japanese crab fisheries pots are employed only in a sector of Hokkaido waters for catching Korean crab.

In the bottom gillnet vinylon is the principal kind of twine used, with spun nylon also used to some extent. (For specifications see Table II and Fig. 14.)

Table II.—Specifications of crab gillnet in vinylon and spun nylon.

For a vinylon net, the netting:—
6 meshes: Vinylon 20s/21 z3.
half-mesh top and bottom:
Vinylon 20s/24 z3.
Mesh size: 50 cm.
Net length: 240 meshes.
Depth: 7 meshes.
Knot: English.

For Spun nylon net:—
6 meshes: Vinylon 20s/21 z3.
Half-mesh top and bottom:
Vinylon 20s/24 z3.
Mesh Size:
Net length: (Same as above).
Depth:
Knot:

Hanging Twine:—
Spun nylon 20s/36 z3.
Floats and sinkers are fastened tightly to the float and sinkerlines at intervals of every third and fourth mesh, respectively, with hanging twines using the double clove-hitch tying method.
Distance between fastening points: On floatline: 59 cm.
On sinkerline: 71 cm.
The same for spun nylon net.

Floatline:—
Manila twine, thickness: 5·7 gm.
Lay: three strands, right twist.
Length of netting in hung measurement: 47·20 m.
End rope on both ends: 67 cm.
Total length: 48·54 m.
The same for a spun nylon net.

Sinkerline:
Manila rope.
Strands: 2×3.
Thickness: 45 gm right twist.
Length in hung measurement: 42·60 m.
End rope on both ends: 1·10 m.
Total length: 44·80 m.
The same for a spun nylon net.

Hanging-in:—
On floatline: 120m/47·20 m.
On sinkerline: 120m/42·60 m.
Same for a spun nylon net.

Treatment:—
Netting: Resin-treated.
Float and sinkerlines: Dyed in Canadium.
For spun nylon:—
Netting: Hairs burnt, resin-treated.
Float and sinkerlines: Dyed in Canadium.

Remarks:—
Polypropylene is now regarded as a promising fibre for crab gillnets because of its light weight and water-repellent property but it is still in the experimental stage.
For sinkerlines, manila hemp is gradually being replaced by synthetic fibre, such as vinylon (45-50 gm) and spun nylon (45-50 gm).

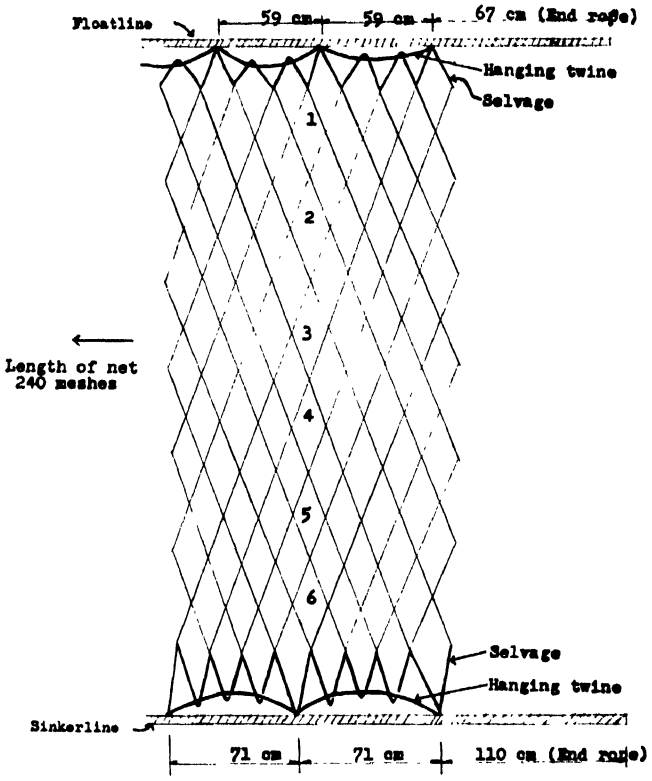


Fig. 14. Specifications of crab gillnet.

Other gear components are small glass float spheres of 8·5 cm diameter, each enveloped in a five gm palm coir netting to which is attached a four gm manila twine of 54 cm length. These floats are tied to the fishing nets at the rate of about 10-12 per net. These floats together with other auxiliary equipment are shown in Fig. 15. The equipment required for a set of 200 nets is: 2,400 small glass floats, 1,200 concrete sinkers, eight large glass floats, two net anchors, four stone sinkers, six weights for six bamboo poles, two large flags, seven small flags and 16 lines.

Concrete sinkers.—each weighs one kg, measures 10 cm in diameter and is 7·5 cm thick; to it is attached a five gm manila twine 60 cm long tied to an imbedded galvanised wire. Six or seven are used per net.

Glass floats (large).—Each float 36 cm in diameter,

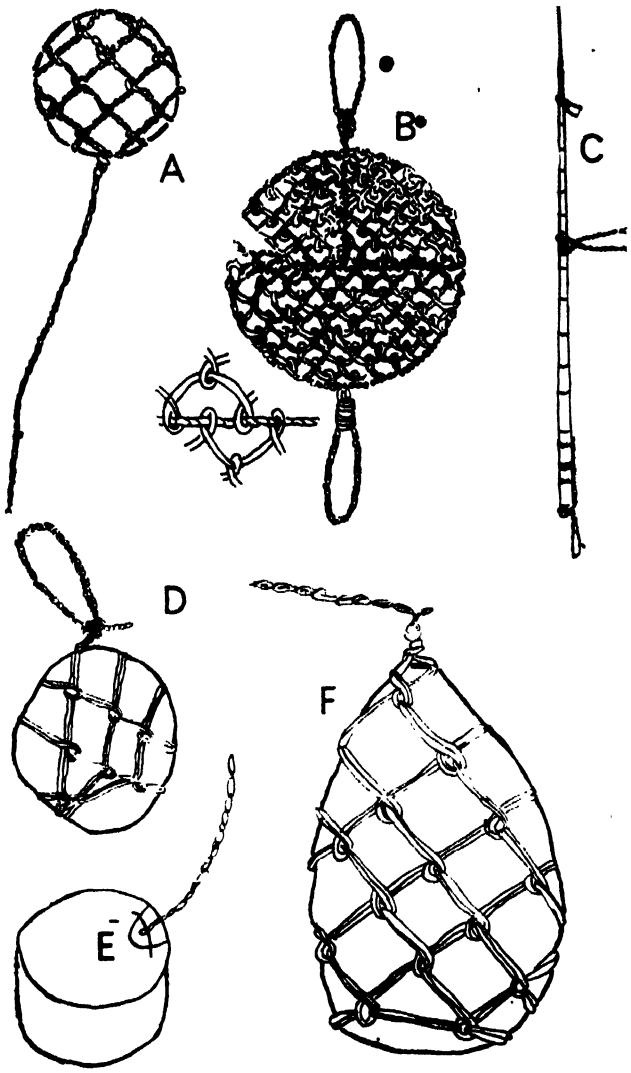


Fig. 15. (a) Glass float (small), (b) glass float (large), (c) bamboo pole, (d) weight for bamboo pole, (e) concrete sinker, (f) stone sinker.

is enveloped with a netting of used 45 gm manila rope or 10 mm diameter straw rope. A loop is formed at both ends and one is connected to the rope at the middle of the bamboo pole and the other to the buoyline.

Weights for bamboo poles.—A naturally rounded river stone of eight to nine kg in netting of used 45 gm manila twine is attached at the lower end of the bamboo pole to make it stand upright.

Stone sinkers are attached to the middle part of the joining lines connecting one group ("ma") of nets (each "ma" consists of 35-40 nets) with another.

Bamboo poles of 10 cm circumference and approximately six m length are used.

Iron stock anchors of 10 kg weight are used for anchoring the ends of nets to prevent drifting.

Flags (large) of either cotton or nylon and measuring 63 cm × 96 cm and of various colours, are attached to the poles at both ends of each set of nets as fleet identification markers.

Small flags of cotton or nylon material and measuring 43 cm × 43 cm indicate each group of nets in various colours.

Wooden tags, buoylines, joining lines and anchor lines complete the equipment associated with the nets.

A nethauler (Fig. 16) is installed on the port foredeck

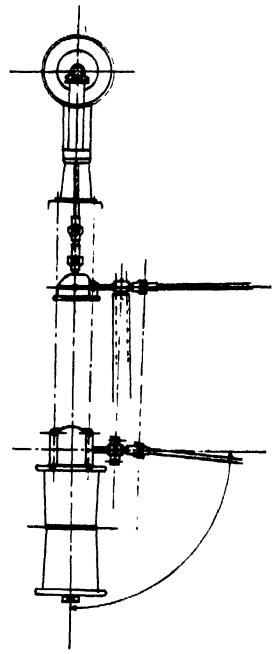


Fig. 16. Nethauler.

of both the clippers and Kawasaki's for hauling in the nets by means of a drum powered by a connecting rod from the main engine. Usually capable of handling about 20 nets per hour, the hauler is operated by extending it over the side at almost right angles to the ship's centre line and running the net through the groove in the middle of the drum.

A grapnel anchor, weighing 8-10 kg, is used for dragging the sea bottom for hooking the sinker lines and nettings with its claws when breakage occurs.

Operation of net

Nets are set when a favourable fishing ground has been found by a surveying ship. The nets are mainly set by the clippers, although Kawasaki boats are sometimes used at the outset. After the Kawasaki's have left early in the morning to haul in the nets already laid, work is commenced on loading the clippers with fishing gear. Clippers, of 80-ton class, take aboard a day's supply of nets (approximately 1,400-1,600 nets) and auxiliary equipment, while the 100-ton class carry a two days' supply (approximately 2,600 nets). En route to the net-laying grounds, the nets are stacked on the poop deck in groups of 35-40 nets each, with the floatline aft and the sinkerline foreward; while on the foredeck due preparations are made on the lines.

Upon arriving at the spot where the nets are to be set, the vessel stops to windward and uptide. Laying speed will vary with conditions but is usually about four knots.

The time required for laying one set ("ha") of nets (e.g., five groups of 40 nets each, or a total of 200 nets) is between 50 and 60 minutes.

After completing one set of nets, the clipper returns to the starting point along the chain of nets just laid, which takes about 30-40 minutes, and proceeds to lay the second set of nets parallel to the first set, keeping a distance of 250-350 m. For setting and operation of crab gillnets see Fig. 17.

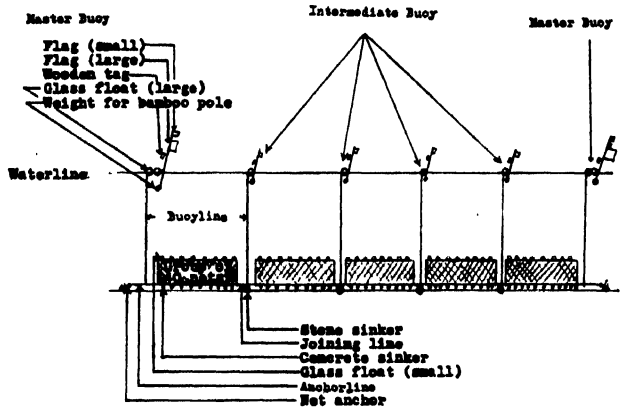


Fig. 17. Sketch of operation of crab gillnets (example of one set of 200 nets comprising five groups of 40 nets each).

Nethauling

The nets which have been laid are hauled in after a lapse of three to four days. While heading for the nets, a wire basket, 2·10 × 2·40 m (7×8 ft), is spread out in each of the fish hatches and a table for removing the crabs from the nets is set up over the hatches. The hauling operation is usually begun at the uptide and windward end of the nets. The crabs are removed and dropped down the hatches. The female and undersized (less than legal size) crabs are carefully removed and returned to the water. The Kawasaki boat then returns to the ship (Fig. 18). Capacity per trip is about 2,000-

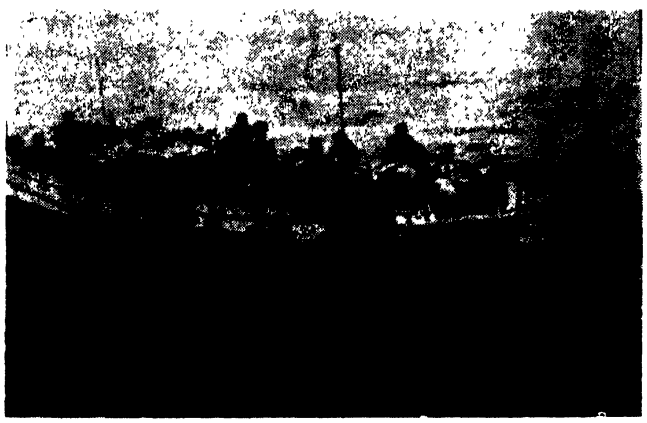


Fig. 18. "Kawasaki" boat returning to factoryship with full load of crabs.

2,400 crabs of 145 mm size. The time extended per trip is generally about six to eight hours.

Longlining is new and successful

by Hiroshi Tominaga
Taiyo Fishery Co., Tokyo

MOTHERSHIP bottom longline fishing has developed to its present form since 1960 as a result of experimental fishing carried out during the period 1957-59. The fishing is mainly conducted on the continental slope in depths ranging from 150-800 m which forms an intermediate zone between the continental shelf and the deep-sea areas of the Bering Sea eastward of 170°E.

The first operations were mainly carried out in depths of 150-350 m off the coast between Cape Oliutorsk and Cape Navarin. Technical improvement to the fishing gear, especially the mainlines, but also in the operational technique, has extended fishing to a depth of 800 m and sometimes even more, so that the operational area has now been extended as far as the Pribilof and Aleutian Islands, covering more or less the whole Bering Sea. The species caught are mainly cod, sablefish, halibut, red rockfish, arrow-toothed halibut, etc., but the catch composition of these species depends on the operational depth. Cod are normally found in depths of 100-200 m, while sablefish are abundant in depths ranging from 450-800 m and constitute the largest catch. Operations conducted in 300-500 m normally result in a mixture of the above species.

Weather conditions restrict the fishing season to about five months, from April to the latter part of September.

A fleet normally consists of a mothership, several catchers and one or two supply-transport ships. The mothership can be of several types, ranging from 500 GT to 10,000 GRT, and will have a number of operational catcher boats, according to her size, as follows: 500 GT mothership—2-3 catchers; 2,000 GT mothership—7-8 catchers; 4,000 GT mothership—15-16 catchers; 10,000 GT mothership—25-30 catchers.

The mothership vessels are all equipped with freezing equipment and refrigerated holds, the major part of the catch being processed into frozen products.

Some of the larger motherships are also equipped with fish reduction plants and produce fish meal, fish oil and liver oil from offal as well as from the cheaper fish species caught.

Supply-transport ships are normally of about 500-1,500 tons. They have large cold storage space for the frozen products and commute between the home ports at about 11-13 knots.

The catchers are mostly wooden vessels of 50-100 tons, with an average of about 85 tons. An 85 GT vessel has an overall length of 26 m, a beam of 5·50 m and a depth of 2·50 m, and is powered by an engine of 270-310 hp, the crew normally consisting of 18-20 men. The vessels are equipped with wireless, radio telephone, direction

finder and echo sounders; in recent years several catchers have been fitted with radar and Loran.

For operating they have a linehauler on the main deck and storage space for stacking the longline gear at the stern. The vessels are necessarily very seaworthy to stand up to the heavy weather.

Longline fishing gear consists of mainlines, branchlines and hooks see Figs. 19 and 20.

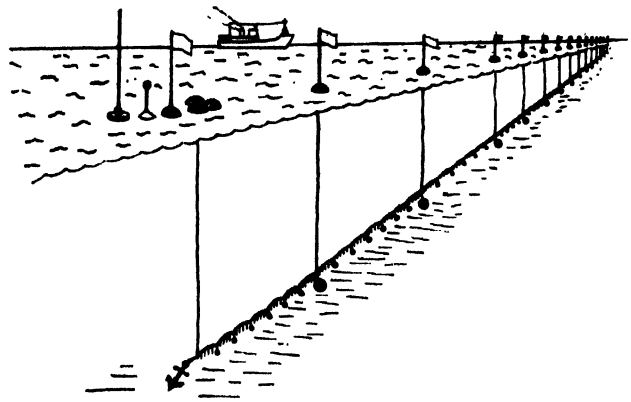


Fig. 19. Bottom longline layout.

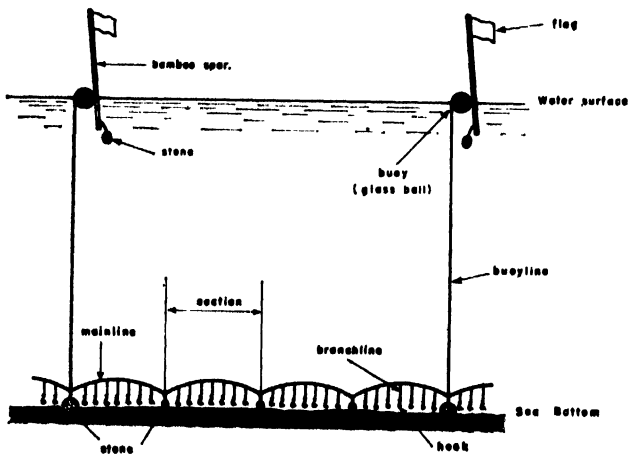


Fig. 20. Bottom longline assembly.

Owing to the depth at which fishing is carried out and to guard against chafing on the bottom, the mainlines normally have a tensile strength of 750 kg. Formerly made of manila or 'Kuralon' (vinylon) the lines are presently a mixture of polyethylene and 'Kuralon' with a weight of about 33 g/m and a diameter of eight mm.

The branchlines are normally made of 'Kuralon' No. 5/15: A skate of longline is 75-100 m long and the number of branchlines varies according to the method of operation. When the hooks are baited while the line is being shot, a section has 27-30 branchlines; when the hooks are baited beforehand a section carries 35-40 branchlines. Baiting the hooks while shooting has the advantage that less bait falls off the hooks during shooting. The branchlines are 1·20-2·00 m.

A complete longline consists of 250-300 sections of a length of 20-25 km. On hauling, each section is coiled in a bamboo basket ready for further operations.

The longline gear includes buoys and buoylines, anchors, bamboo spars, light buoys, radio buoys, etc. The buoylines are adjusted in length so that the line can settle on the sea bottom and usually are from 1·3-1·5 times the sea depth, according to tide and/or current.

Marker buoys, carrying lamps and set at appropriate distances assist in retrieving gear in darkness and when lines snap. A set of longline normally carries a radio buoy at each end to locate the gear during fog.

Lines are baited before shooting with defrosted cuttle fish, or else baits are attached as the line is shot. Shooting is over the stern and starts about 18.00 or 19.00 hrs. A stone of about one kg is attached at the junction of each section. A buoy is attached at every 30-40 sections and a weight of 10-15 kgs is hung on to the tie-up of the buoyline to the mainlines. During shooting the vessel keeps a speed of about seven knots so that a shooting speed of 200-230 sections per hour is achieved. The vessel then drifts until 03.00 or 04.00 hrs when hauling starts. The main marker buoy is picked up and the line led in over the side roller on the gunwhale to the linehauler. As each section of line comes in it is disconnected and coiled in its basket, and carried to the stern for stacking. Under favourable conditions, the line is hauled at an average of 27-30 sections per hour. The fish are dehooked, sorted by species and stowed in large polyethylene baskets for trans-shipment to the mothership.

Up to the present, echo sounding has not been very effective in locating fish on the bottom, and fishing grounds are mainly determined according to the depth, and past experience. Depth contour lines and the nature of the bottom serve as additional indicators.

The mothership normally positions herself more or less centrally to the location of her catchers, with her port side to windward and pneumatic fenders hung out ready to receive the catchers alongside. Transfer is made every day as the catchers moor to the mothership. During the trans-shipment fuel oil, fresh water, provisions, bait, fishing gear, etc., are replenished.

Goro Okabe

Catching Tuna by Longline is Efficient

THE Japanese tuna longline fishing operations are conducted in three different ways using three distinct types of vessels.

Individual longliners are based on the Japanese home-

land, certain islands in the South Pacific, or operate in the Atlantic Ocean. These vessels return to their base at the end of each trip to land and market their catch.

Mothership carrier vessels carry up to eight catcher boats and operate during three to six months in the Atlantic, East Pacific or Indian Ocean, or conduct continuous operations in the Atlantic over a period of about two years.

Mothership fleet vessels are of about 3,000 to 10,000 GT and operate continuously for about six months with 40 to 50 subordinate catcher vessels of 100-200 GT. These fleets are at present operating mostly in the South Pacific. The main advantage of this type of operation is the gain in fishing time. While in the past the catch was iced and brought to Japan by individual fishing vessels of 100-200 GT, mothership operation saves the time spent in steaming to and from the fishing grounds, by refrigerating the catch on board.

Since the first typical mothership fleet started operations in 1950, two or three new fleets have been organised every year, making a total of 45 fleets today. Because of the decreasing catch both in inshore and offshore fishing in Japan, the operations are usually conducted about 4,000 miles from the base.

The law requires that every catcher boat should be a longline fishing vessel of 40-300 GT. The most convenient type is of 100-150 GT. Such a vessel can operate for 50-80 days continuously.

A complete longline has about 2,000 hooks divided into about 400 baskets. The line is shot with the vessel steaming at nearly full speed and the setting operation usually begins at 03.00 hours, lasting for about five to six hours. As soon as the lines are set, the crew go off duty by shifts. At noon, hauling of the line begins and this lasts about 10 to 12 hours depending on the catch.

The catcher vessels work this daily routine around their chosen fishing area. They rarely operate for more than 10 days in one area, nor do they work at more than 1,000 miles away from the mothership.

Fishing gear

Each catcher boat has 350 to 400 baskets of longlines, all lines being constructed as in Fig. 21. The total length of the line is about 130 km, but, owing to the slack given during setting, the actual distance from end to end while fishing is only 60-70 km.

Each basket is made to the following specifications:

	Length	*Gauge*	*Material*	*Quantity*
Buoyline	23 m	50 ply	'Kremona'	1
Mainlines ..	47 m	50 ply	,,	6-7
Branchlines ..	11 m	40 ply	,,	5-6
Sekiyama ..	8 m	No. 28	Steel	5-6
Snood wire ..	2·5 m	No. 28	,,	5-6
Hook	10 cm		,,	5-6

Every basket has one 33 cm diameter float to hold up the lines. Three radio buoys and 13 lightbuoys are normally used to mark the gear.

A complete set of gear can be used for about 350 operations or about two to two and a half years and must then be renewed. The vessels are fitted with line haulers and rollers appropriate to their size.

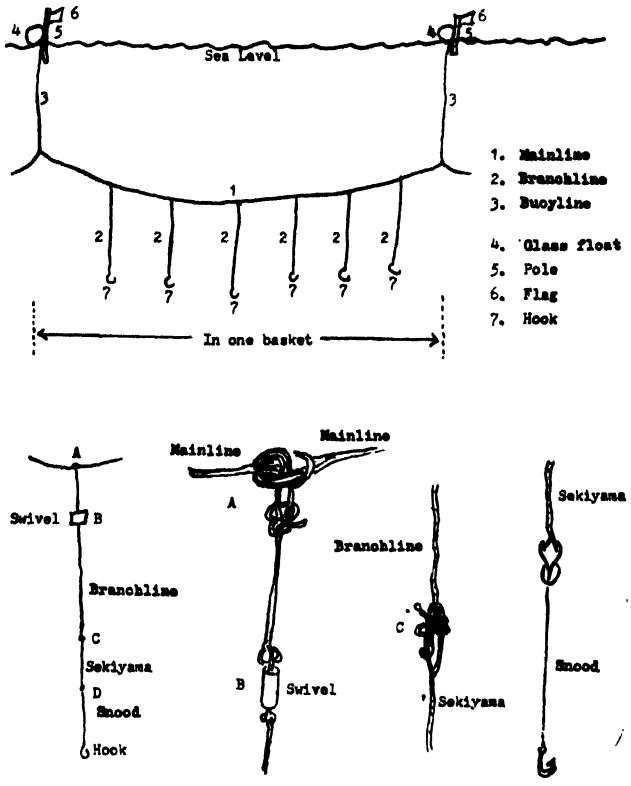


Fig. 21. Details of tuna longline construction.

Bait

Bait is stored in wooden or cardboard cases, each containing 110 pieces. Frozen mackerel pikes of 100-140 g each are used as bait, the 100 g bait being suitable for albacore fishing. Freshness is important to prevent it falling off the hooks.

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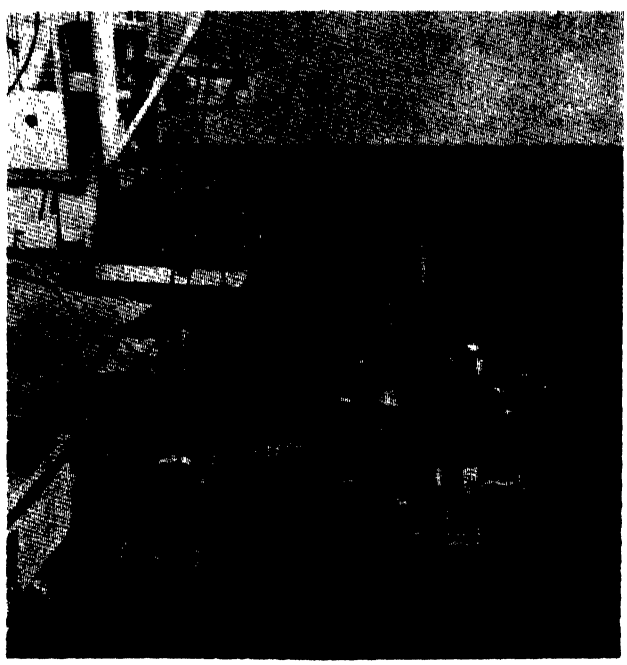

Fig. 22. Catcher boat unloading.

Las Pesquerias Españolas Austro-Atlanticas

by
V. Paz-Andrade

Vigo, Spain

Extracto
Todos los precedentes europeos del experimento español ocurrieron en el Atlántico norte y aun los más perfeccionados tecnicamente no salieron de los límites geográficos clásicos. En el último semestre de 1961 las dos primeras unidades totalmente congeladoras de la flota española realizaron los viajes iniciales. Se trata de dos barcos iguales, de eslora total de 52 m y desplazamiento 880 tons. Uno se dirigió al este de la Patagonia y el otro al suroeste de Africa; una distancia de 5,000 y 4,500 millas respectivamente. Obtuvieron resultados espléndidos y en tres meses regresaban a Vigo con una carga completa de excelente pescado congelado. En 1962 se agregaron cuatro unidades congeladoras nuevas, algunas de 56·20 m de eslora y 960 tons de desplazamiento, con motor de 1,250 hp, y en 1963 el número se ha elevado a ocho, estos dos últimos arrastreros con rampa a popa. El viaje redondo es de 90 u 80 dias. Esto supone la posibilidad teórica de realizar cuatro expediciones anuales pero en la práctica no seria asequible ni aun si la velocidad se elevara de los 11 ó 12 nudos actuales a 13 ó 14 y la base se desplazara al sur de España en el puerto de Cádiz. Se decidió por ello para aprovechar hasta el máximo la capacidad de los barcos, o sea, pescando con el mismo número de barcos más días, recurrir al mercante frigorífico que recoge la pesca de los arrastreros congeladores y la lleva a la base mientras éstos continúan la faena o recurriendo al buque-madre. En el experimento español se han empleado ambas soluciones. El buque-madre aceptará las capturas de 10 arrastreros que llevará el pescado en agua de mar refrigerada a 2°C. Cuatro de estos 10 iran dotados de motones motrices Puretic para dedicarlos a las capturas de superficie, aunque también llevarán artes flotantes y de fondo para usarlos cuando convenga. En los buques mercantes se instalará equipo de congelación para congelar la captura de los arrastreros que no lo lleven o que prefieran entregar sin congelar el producto de los últimos lances. El buque-madre tendrá una capacidad de 7,000 tons de pescado congelado, podrá congelar filetes y fabricar 1,500 tons de harina y como se confía que pueda hacer por lo menos dos viajes al año, sus descargas totales de producto de primerísima calidad serán considerables e indudablemente influirán en los precios de venta al público de las especies particulares de que se trata, que son merluza capensis y hubbsi tan apreciadas en el mercado español. Representan estas dos merluzas el 90 por ciento de la producción. El 10 por ciento restante lo forman el congrio colorado, el jurel de gran tamaño y otras pocas especies aprovechables más. De la operación austral se esperan enseñanzas útiles sobre el comportamiento de los artes de pesca.

The Spanish South Atlantic Fisheries

Abstract
Prior to the Spanish experiment described here, European distant-water fishing had been mainly in the North Atlantic, and even the most technically advanced kept within the old geographic limits. In the latter half of 1961 two freezer trawlers of the Spanish fishing fleet left port and set course, one for the grounds of the Patagonian Shelf in the South-Western Atlantic and the other for South-West Africa, a distance of 5,000 and 4,500 miles respectively. Both of them were side trawlers of 52 m total length and 880 tons displacement. About three months later, after a successful trip, they returned to their base in Vigo with a full load (about 250 tons) of excellent frozen fish. In 1962 four new freezer side trawlers of 56·20 m total length, 960 tons displacement and main engine of 1,250 hp, were added to the fleet; and in 1963 two more units, both sterntrawlers of over 1,000 tons displacement, have gone out to those distant grounds. The round trip takes from 80 to 90 days. Theoretically four annual trips are possible but in practice this is not attainable even if the present speed of 11-12 knots were increased to 13-14 knots and the base were transferred to the southern Spanish port of Cadiz. In view of that it was decided to increase as much as possible the production of the vessels by keeping them permanently on the fishing grounds and transferring the catch to refrigerated merchant ships or to a mothership. Both methods are being used in the Spanish experiment. In the refrigerated merchantmen, to which the catch will be trans-shipped in the nearest convenient port, freezing equipment has also been installed. The mothership, a converted passenger ship, will take the catch of ten trawlers which will be fitted with seawater tanks, refrigerated at—2°C. Four of these trawlers will carry midwater and bottom trawls as well as Puretic power blocks for surface fishing. The capacity of the mothership will be 7,000 tons of frozen fish plus 1,500 tons of fish meal which will be processed on board. She will also be equipped with filleting machinery. As it is hoped that she will be able to do two round trips per year, well over 15,000 tons of quality products will be unloaded in Vigo. About 90 per cent of the catch is hake (*Merluccius capensis* and *M. hubbsi*). The other 10 per cent is made up by king-klip (*Genypterus capensis*), very large horse mackerel, smooth (*Macruroplus nigromaculatus*) seasonly, and a few other commercial

Continued from page 437

Mothership and catcher boats communicate with each other three times a day on special wave-lengths. Wireless operators are on duty in shifts all round the clock.

Every catcher boat (Fig. 22) reports on the following subjects twice a day:

(a) Before dawn: Number and weight of catch previous day, classified by species; operating position, weather, wind, temperature, water temperature, programme (bound to fishing grounds; to mothership; shifting fishing grounds; setting lines; hauling lines; ceasing, etc.).

(b) In the evening: Noon position by observation, weather, wind temperature, water temperature, hour and course of setting line, number of hooks used, number of operations and direction and velocity of current.

Catcher boats are generally equipped with thermometers and electric thermographs for surface water, water colorimeters, echo sounders, etc. Very few are equipped with bathythermographs, hydraulic barometers and thermometers.

Catcher boats pay great attention to the movements and operations of other boats fishing in the adjacent areas and inform each other of catch rates by radio.

Although echo sounders detect the "deep scattering layer", tidal shifting and even single bodies of tuna at times, their usefulness has not been finally decided as yet.

The mothership usually appoints two or three catcher boats as research boats to find richer fishing grounds. They survey the surface and deep-water temperatures, etc., while conducting operations for themselves.

The mothership decides the adequacy of fishing grounds and gives instructions after correlating the information received from research boats and catchers.

species. It is expected that, from these southern operations, some useful experiences on the performance and effectiveness of fishing gear may be gained.

La pêche dans le sud Atlantique Espagnol

Résumé

Avant l'expérience espagnole décrite ici, la pêche hauturière européenne était principalement pratiquée dans l'Atlantique du Nord et même les plus avancés techniquement se tenaient dans les anciennes limites géographiques. Au cours du deuxiéme semestre de 1961, deux chalutiers frigorifiques de la flotte espagnole quittaient Vigo, l'un se dirigeait vers les fonds du plateau Patagonien dans l'Atlantique du sud-ouest, l'autre vers l'Afrique sud-ouest, à une distance de 5,000 milles et de 4,500 milles, respectivement. Les deux chalutiers étaient de 52 mètres de long, d'environ 880 tonnes et opéraient par le côté. Trois mois plus tard ils rentraient à leur base avec 250 tonnes de poisson congelé excellent. En 1962, quatre nouveaux chalutiers frigorifiques, chacun de 56·2 mètres de long, 960 tonnes et ayant des machines de 1,250 cv furent ajoutés à la flotte et en 1963, deux autres unités de plus de 1,000 tonnes, ces dernières opérant par l'arrière, sont parties pour ces lieux de pêche lointains. Le voyage aller-retour durant de 80 à 90 jours, théoriquement, quatre voyages par an sont possibles mais dans la pratique cela est impossible, même si la vitesse de 11 à 12 noeuds des bateaux est augmentée jusqu'à 13 ou 14 noeuds et la base transférée à Cadix, au sud de l'Espagne. On a donc décidé d'augmenter la production des bateaux autant que possible, en les laissant constamment sur les lieux de pêche et en transbordant la capture sur des bateaux de commerce frigorifiques ou sur un bateau-mère. Les deux méthodes sont utilisées dans cette expérience espagnole. Les bateaux frigorifiques de commerce ont été pourvus de l'équipement nécessaire et les captures seront transportées au port le plus proche. Le bateau-mère un paquebot converti, prendra la capture de 10 chalutiers équipés avec des réservoirs à eau de mer refroidie à —2°C. Quatre de ces chalutiers seront équipés avec des chaluts pélagiques et des chaluts de fond aussi bien qu'avec des poulies "power blocks Purétic" pour la pêche à la surface. La capacité du bateau-mère est de 7,000 tonnes de poisson congelé et de 1,500 tonnes de farine de poisson produite à bord. Le bateau aura aussi des machines à fileter. On espère que le bateau-mère pourra faire deux voyages par an pendant lesquels 15,000 tonnes de produits de première qualité seront déchargés à Vigo. A peu près 90 pour cent de la capture se compose de merlus (*Merluccius capensis* et *M. hubbsi*). Les autres 10 pour cent des kingklip (*Genypterus capensis*), très grands saurels saisonniers (*Macruroplus nigromaculatus*) et quelques autres espèces commerciales. On espère que de ces opérations dans le sud on obtiendra une expérience pratique concernant la performance et l'efficacité des engins de pêche.

EL fenómeno de mayor calado, que está produciéndose en la economía pesquera mundial, parece identificarse con el cambio de perspectiva y dimensión en el uso de los recursos del mar. Las ideas de corto vuelo espacial sobre la accesibilidad a la apropiación están perdiendo vigencia. Simultáneamente, ciertas posiciones consagradas sobre determinados modelos de explotación comienzan a quedar desplazadas por otras mucho más dinámicas.

Hasta hace pocos años este proceso revestía la forma de mero alargamiento lineal de la órbita de pesca. Siempre con las limitaciones propias de las unidades navales de tipo tradicional. Tal es la frontera quebrada por el impacto de la tecnologia moderna. La proyeccion que ésta adquiere puede constituir una respuesta convincente a las penurias de la "overfishing" y una contribución positiva a la lucha universal contra el hambre.

Para ello será necesario que al incremento de la potencialidad de captura y consiguiente movilidad de los factores se añada otro elemento. El de una mejor redistribución de los recursos sin mengua de su conservación. Dentro de la nueva tendencia ha despertado interes en la esfera internacional la expansión hacia el hemisferio sur emprendida desde base española. El desarrollo de tal experiencia no ha llegado al apogeo, pero ya permite obtener algunas deducciones de naturaleza técnico-económica con significado orientador para la evolución futura de la pesca a larga distancia.

Relación entre factor natural y factor técnico-económico

Comencemos por analizar el papel de las fuerzas productivas dentro de la moderna dinámica de las pesquerías. La relación existente entre el factor biológico y el factor técnico, como aferentes a la formacion del producto bruto, viene ahora evolucionando hacia el predominio del segundo.

Antes eran las condiciones naturales favorables las que predeterminaban el mayor rendimiento. La anchura de la plataforma arrastrable, su inmediación a las bases, la concentración permanente o estacional de biomasas, la adhesión litoral de ciertas corrientes profundas y en todo caso la distancia a las áreas más fértiles, han jugado papel decisivo en el crecimiento de las grandes potencias pesqueras.

Copiosos ejemplos podrían patentizar la prioridad asumida por los favores de la naturaleza en el desarrollo de las más prestigiosas estructuras industriales cimentadas sobre las riquezas del mar. Algunos como el Japón, Perú, la U.R.S.S., Noruega, Sudáfrica, Canadá, Islandia, etc., parecen ejemplos típicos. El primero, el tercero y otros han dejado de serlo.

Sin que el factor biológico perdiera su fuerza como clave del rendimiento, el factor técnico-económico asume cada día nueva preponderancia. Incluso los países que encabezan la escala mundial de los grandes productores no apoyan todos su jerarquía en la vecindad de las fuentes. En cambio, siempre gana terreno la inversión en equipos dotados de movilidad y capacidad suficientes para tornar accesibles grandes masas de recursos que se tenían como situados fuera de la órbita de una explotación rentable. La relación equipo-rendimiento acentúa cada vez más su prioridad.

El lanzamiento de nuevas flotas sobre el mapa de los mares responde ahora al principio de la dispersión contrapuesto al de la concentración operacional. Se dirige hacia fondos densamente poblados, aunque resulten remotos. Norteamérica puede considerarse precursora de este despliegue al establecer una base atunera en Samoa y al enviar "tuna clippers" hasta el archipiélago de Galápagos recorriendo más de 3,000 millas. Después, pasando del Pacífico al Atlántico, establece bases industriales en Puerto Rico y Africa ecuatorial. Desde el mar Amarillo el Japón se proyecta sobre el Pacífico americano y australiano primero, y después se introduce en los hemisferios norte y sur del Atlántico. La U.R.S.S. canaliza su expansión hacia las mismas latitudes llegando hasta los bancos de Terranova. Y España, al armar su primera flota congeladora, la destina a los fondos remotos del Atlántico austral[1].

[1] Compañía armadora: Pescanova S.A.

Cambio de estructura productiva y cambio de geografía productiva

El fenómeno cuya noción acabamos de esbozar presupone la adopción de enérgicos cambios en el sistema pesquero tradicional. Cambios que afectan a la estructura tanto como al *modus operandi*. Aunque tengan su raíz en la fase de extracción, sus efectos extravasan el marco primario. Se propagan a los ciclos siguientes del proceso productivo sea el de transformación sea el de comercialización.

Un enfoque que restringiera los términos del problema a recoger una mutación estructural de los equipos de captura, resultaría incompleto. Cierto que en la concepción constructiva y funcional del buque de pesca y del aparejo acoplado al mismo, así como de la maniobra de tales elementos mecánicos, es donde se hace más visible el impacto de la innovación técnica. Pero esta innovación reclama otras. Al implantarse en el sistema introduciendo una dimensión nueva, los demás componentes de aquél han de someterse a un proceso paralelo de adaptación.

La necesidad de poner en claro esta relación interna, en la actualidad debe considerarse perentoria. Un respetable y copioso conjunto de intereses industriales se verá directa o indirectamente implicado en el viraje. Es de esperar una reacción de tales intereses ante los incentivos que el fenómeno ofrece. Pudiera resultar desafortunada si se apoyara sólo en el deslumbramiento que origina el avance tecnológico olvidando los demás aspectos, especialmente los económicos.

Ni la posibilidad de incorporarse a nuevos modelos de explotación, ni la complejidad que revisten cuando sitúan su base operacional sobre los recursos de mayor lejanía, son privativas de determinado país. Siempre las ventajas de la localización jugarán su papel con mayor o menor incidencia según los casos. Pero la barrera del radio de acción del buque impuesta por la capacidad de los tanques de combustible, o la velocidad de crucero, ya no constituyen freno reductor de su órbita de trabajo.

Dentro del orden de ideas que comienza a moldear en el mundo un nuevo pensamiento sobre la producción alimenticia de la mar, las enseñanzas de la experiencia española pueden resultar orientadoras. Se trata del testimonio más reciente sin que haya contribuído a forjarlo la ortodoxia tradicional. Tiene el valor de un ensayo deliberadamente concebido para no reincidir en las posiciones heredadas. Responde, por el contrario, al afán de superarlas, mediante la apertura de nuevos horizontes para la producción pesquera.

Antes de ponerse en ejecución el experimento español otros países del mundo pesquero nordatlántico como el Reino Unido y Alemania Occidental, habían introducido en las estructuras clásicas injertos renovadores. Como tales hay que citar siempre a los buques-factoría, los trawlers congeladores, la incorporación a unos y otros del arrastre y maniobra del arte por la popa, la propulsión diesel-eléctrica y otros.

Estas innovaciones a pesar de su audacia técnica no habían alterado sustancialmente la geografía pesquera del continente. En éste no fueron aprovechadas antes de que España las adoptara para asegurar la accesibilidad a nuevas fuentes de recursos cuya plenitud biológica prometiera altos niveles de producción, aun a expensas de costos multiplicados. Esta doble condición valoriza y singulariza la aportación de Galicia a la evolución del sistema pesquero occidental.

Compatibilidad entre distintos tamaños de empresa

El tránsito del patrón clásico de explotación al modelo altamente evolucionado comienza por alterar la estructura de la empresa. Así como del artesanado adherido a la pesca litoral se efectuó el despliegue hacia la unidad industrial capitalizada de tamaño pequeño o medio preferentemente, otro ciclo de la evolución está en marcha. El nuevo se caracteriza por una combinación a escala mucho mayor de los factores productivos comenzando por el capital fijo.

La tendencia cuya proyección describimos no supone ni mucho menos que la empresa armadora pequeña y media haya agotado su misión en la economía pesquera. Así como el artesanado precapitalista ha sobrevivido hasta hoy incluso como vivero humano vocacional del desarrollo industrial, las formas menores de la empresa pesquera—individuales, cooperativas o sociedades mercantiles—mantendrán su actividad sin límite visible en el tiempo.

Lógicamente, con mayor horizonte de prosperidad sobre el futuro. Primero, porque en proporción también aprovecharán los frutos del avance tecnológico general. Después, porque seguirán operando sobre recursos localizados en mayor proximidad a las bases con bajos costos de transferencia. Y, finalmente, porque la disponibilidad de los mismos debe resultar espontáneamente acrecentada al disminuir la presión extractiva que sobre las mismas áreas habrían de ejercer las unidades atraídas hacia caladeros lejanos.

Se trata de esferas distintas del desarrollo pesquero perfectamente compatibles. El crecimiento de una de ellas no debe repercutir en contracción o encogimiento de las otras. Debe, por el contrario, favorecer su vitalidad dentro de las lindes correspondientes al modelo de explotación elegido.

Incluso desde el punto de vista del mercado donde la evolución hacia la macroempresa conducirá a un aumento copioso de la oferta. Sea ésta, o no sea, creadora de su propia demanda, el déficit de alimentos proteínicos que la humanidad aún padece, absorberá cada día mayor proporción de los que gratuitamente entrega el mar a diario.

Dimensiones principales de la macroempresa

En la configuración de la empresa que está surgiendo predestinada a proyectarse más allá de las fronteras que se había impuesto la industria tradicional de las pesquerías, domina sobre los demás caracteres el del crecimiento de sus dimensiones. Tanto el de las dimensiones económicas como el de las técnicas. Y así con referencia al volumen como a la complejidad de las estructuras. Para ofrecer una imagen más demostrativa del fenómeno, conviene analizar, aunque sea sumaria-

mente, sus elementos esenciales:

(a) Aumento de los costos de financiación.—Para emprender la construcción de unidades especiales, cuyo calculo, diseño y equipamiento respondan a prototipos técnicamente avanzados, la primera barrera a vencer surge de la magnitud de la inversión. Será necesario realizarla en proporción que duplique o triplique el nivel ordinario del costo de financiación. Esta proporción aproximada puede admitirse como valedera en la relación entre el moto-trawler tradicional y el moto-trawler congelador, y entre el primero y el "stern freezer trawler", con aquellas demasias de capacidad en los segundos que reclaman el prototipo al cual se ajusten y la tasa de rentabilidad esperada.

Sobra decir que en el cálculo de rendimientos las deducciones de costos para retribuir el capital de préstamo, adquieren mayor incidencia. La que corresponde al interés y al plazo de reembolso cuya doble gravitación debiera producirse en relación inversa y directa, respectivamente, al volumen de la inversión y la vida probable de la unidad financiada.

(b) Aumento del nivel de capacitación técnica.—Dentro de los prototipos modernos el elemento maximo de diferenciación radica en el uso del frío industrial. El montaje a bordo de la congelación rápida, sea para parte de la carga, sea para la totalidad, bien mediante túneles circulados por salmuera o chorros de aire helado, bien utilizando armarios divididos con placas para enfriar por contacto, determina la necesidad de aptitudes profesionales especificas. Tanto para el entretenimiento del equipo frigorífico, su manejo y reparación, como para el proceso de los productos capturados que supone la creación inmediata de una mercancía distinta mucho más resistente y de más intacta composición que la almacenada entre capas de hielo.

La especialización también recae en la maniobra del arte. Tanto por cambio de la forma y materiales con que esté confeccionado, como porque intervenga mayor automatismo para largar o izar, ya sea usando rampa trasera o pórtico basculante, ya sea utilizando "power-block" para aparejos de superficie u otro dispositivo mecánico destinado a la misma maniobra.

En un tercer aspecto, los elementos destinados a la orientación náutica, la telecomunicación y la detección de bancos, deben entrar en este recuento. Aunque se trate de dispositivos de utilización general necesitan extremar su eficiencia y afinamiento cuando se instalen en buques llamados a grandes recorridos donde los errores de enfilación, los retardos en la localización de los bancos, las colisiones previsibles, etc., pueden irrogar considerables pérdidas.

(c) Asunción del proceso de commercialización.—La función de la empresa armadora tradicional puede darse por terminada al entregar sus productos al licitador que los remata en la subasta. Cuando la oferta se compone de mercancías no sujetas a descomposición acelerada, la situación es distinta. Uno y otro tipo de oferta se destinan al mismo consumidor, pero el sistema de distribución forjado para la comercialización del pescado fresco no siempre resultará utilizable para los productos congelados.

Primero, por resistencia al cambio de la estructura comercial preexistente. Después, porque al proceso de fijación que deriva de la congelación rápida, también contribuye a la estabilidad de precios, asimilando los productos, especialmente si se lanzan con presentación homologada, a los manufacturados del ramo de la alimentación.

Para que la empresa armadora pueda independizarse de la comercialización directa, sería necesario disponer de organizaciones generales de distribución apoyadas en la cadena nacional del frío. Donde no existan aún, también el tamaño de la empresa que desarrolla la producción primaria habrá de ensancharse hacia el mercado, si quiere defender con eficacia el ingreso derivado de la venta de sus productos, y contribuir al equilibrio del sistema general de precios.

La necesidad de que sea asumida la distribución por la unidad productora, diferirá de un país a otro. La circunstancia de que en España se haya producido tal fenómeno obliga a pensar que, con mayor o menor agudización, podrá repetirse allí donde las posiciones adquiridas a favor de la especulación con el pescado fresco hayan hecho inviable por el momento la creación de alguna organización distribuidora especializada y autónoma.

La opción entre dos hemisferios

Todos los precedentes europeos del experimento español tuvieron como escenario el Atlántico norte. Aun los que alcanzaron mayor dimensión técnica no ampliaron la dimensión geográfica dentro de la cual venía operando la flota clásica. Las unidades más modernas—buques-factoría, semicongeladoras, congeladoras, "stern trawler's", etc.—volvieron a calar sus aparejos en los fondos sometidos desde hace siglos a la mayor intensidad de captura.

Esta evolución se inició por el Reino Unido al mediar la década de los años cincuenta. Fue pronto secundada por Alemania Occidental. No obstante, cuando en 1960 se concibió la empresa y se planeó la flota, que desde un puerto de Galicia había de introducir cambios radicales en el modelo de explotación hasta entonces vigente, la experiencia centroeuropea sobre buques congeladores era corta y más tímida que alentadora.

Pronto se echó de ver que en la flota europea de factura novísima, al gran adelanto técnico y a la magnitud de la inversión, no correspondía un aumento espectacular de la productividad marginal. Parecía claro que la causa del fenómeno debía atribuirse exclusivamente a la baja concentración de la biomasa demersal en los lugares explotados.

Así se perfiló con claridad la opción entre los hemisferios norte y sur. Entre el norte cercano, con sus áreas biológicamente fatigadas, y el sur lejano, mucho más lejano, pero con una disponibilidad de recursos superdensa y parcialmente ociosa. El dilema se resolvió en favor de la solución más arriesgada en cuanto suponía una inicial desorbitación de los costos operativos.

En el último semestre de 1961 las dos primeras unidades

totalmente congeladoras de la flota española realizaron los viajes iniciales. Uno a los fondos de la plataforma preantártica que se extiende al este de la Patagonia.[2] Otro a los fondos de la plataforma del suroeste africano.[3]

Durante el año siguiente cuatro nuevas unidades,[4] también congeladoras, y algunas de mayor capacidad, se sumaron a las primeras. En 1963 el número se ha elevado a ocho, las dos últimas con rampa para el arrastre por popa.[5] Esta reincidencia en la localización ultralejana de las operaciones, desarrollada por la misma empresa armadora, constituye un testimonio convincente de que la experiencia austral desde bases europeas puede considerarse consolidada.

Este acontecimiento inicia un cuarto camino. Las rutas pesqueras de Europa ya no terminan en el mar de Barentz o en Jan Mayen al norte, en Terranova al oeste y en Dakar o Freetown al sur. Mas alla de este límite se abrieron nuevas fuentes para la despensa occidental. No es posible prever las dimensiones que podra alcanzar en el futuro la expansión basada en las reservas de energia biologica del Atlantico austral. De cualquier modo, el estadio en que la experiencia se halla, aun siendo inicial, permite obtener, en terminos economicos, algunas consecuencias orientadoras.

Reducción de los costos de operación

Las principales son dos. Consiste la primera en la necesidad de reducir al limite las "external diseconomics".[6] Desde el paralelo 43 N-Vigo al 40 S o a 33 S, con escala en Dakar, cada viaje supone un recorrido de 5,000 ó 4,500 millas. Sumando ida y vuelta, tiempo de operación sobre los caladeros, recaladas en algún puerto próximo y demoras imprevisibles, la duración media de cada expedición no debe calcularse en menos de 90 días u 80, según se trate del destino más o menos lejano. (Fig. 1.)

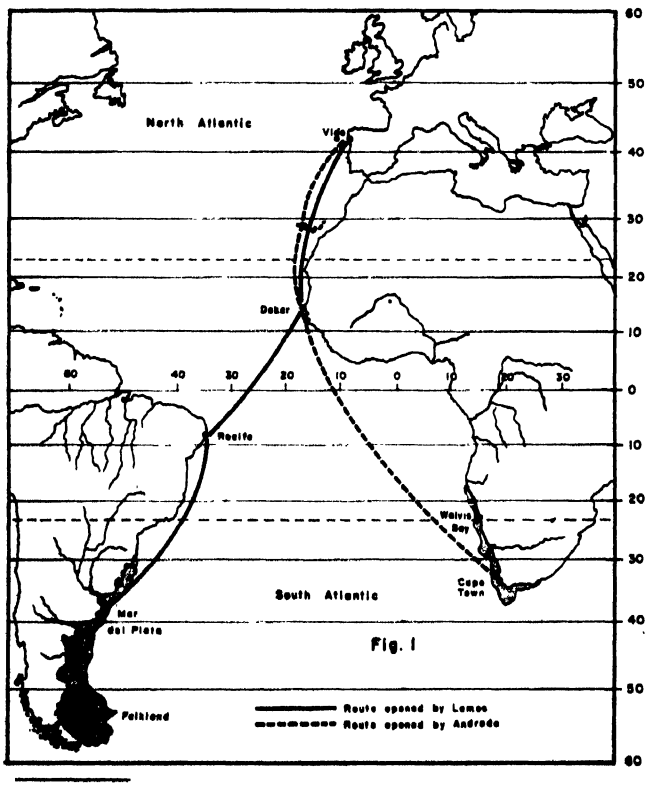

Fig. 1

Esta media supone teóricamente la posibilidad de realizar cuatro expediciones por año. Tal objetivo no sería alcanzado en la práctica aunque la base se desplazara al paralelo de Cádiz. Tampoco sería asequible probablemente aunque la velocidad de crucero de las unidades se elevara de 11 ó 12 nudos a 13 ó 14. Los tiempos perdidos en la descarga del pescado, restauración de desperfectos del buque y afinación de su maquinaria, aprovisionamientos, etc., suponen al año aproximademente la mitad de la duración atribuida a cada viaja redondo.

Comparando la operación ejecutable en el escenario austral y la misma en cualquiera de los escenarios nórdicos, se descubre inmediatamente la forma dispar en que una y otra funcionan. Nos referimos a operaciones emprendidas desde la misma base europea.

No es necesario entrar a discriminar los factores que juegan en cada una, ni su diferente gravitación en los resultados. Bastará destacar que en la primera debe concederse prioridad al volumen de los costos unitarios mientras que en la segunda asume papel principal el volumen de la producción bruta por viaje. Ambos factores están sujetos a fuerte fluctuación, agudizada por el lado de los costos totales.

En la reducción de los mismos reside la clave del problema. Así para moderar los riesgos como para elevar la tasa de productividad marginal. Tal objetivo en la operación de base austral no resultaba atacable ni por compresión de los suministros, ni por supresión de eventuales arribadas, ni por minoración de capítulo de salarios y participaciones.

La solución más acorde a la ortodoxia económica y el interés social era otra. Podía hacerse consistir en el aumento sustancial de la producción unitaria logrado sin acudir al empleo directo de mayores dosis de capital fijo. O sea, pescando con los mismos buques durante un numero mayor de dias, entre el viaje de la base al caladero y el de vuelta. No aplicando a la flota congeladora el esquema dinámico adoptado por la fresquera. Haciendo, por el contrario, uso más idóneo y prolongado de la superioridad de medios comenzando por dar a su empleo la máxima continuidad operativa en la mar.

Para desplegar tal estrategia era indispensable conceder entrada a un nuevo elemento en el modelo de explotación. Así, el circuito que nació homogéneo se hizo mixto. El *modus operandi* amplía su desarrollo incluyendo el trasbordo *in situ*, o en puerto inmediato. A la flota pescadora se asocia el mercante frigorífico. Este zarpa para la base con la carga congelada mientras aquélla continúa la faena.

Transporte autónomo y buque-madre

Dentro de la organización armadora que protagoniza la experiencia europea en las regiones austro-atlánticas, la

[2] Motopesquero congelador "Lemos".
[3] Motopesquero congelador "Andrade".
[4] "Pambre", "Doncos", "Soutomaior" y "Sobroso".
[5] "Villalba" y "Viamianzo".
[6] C. J. Bottemanne D.: "Principles of Fisheries Development," Amsterdam, 1959.

introducción de los trasbordos en la rotación de los "trawler's", pudo suponer la reducción del cincuenta por ciento, o poco menos, del número de transferencias directas por año. No quiere esto decir, ni mucho menos, que la misma proporción valga para medir el incremento de productividad resultante. Ni siquiera por tosca aproximación. Lo que proporciona es una positiva contracción de las deseconomías propias de la pesca a larguísima distancia, permitiendo diluir el costo total forzosamente elevado, en un número mayor de unidades producidas.

Al mismo tiempo, la fórmula acrecienta la regularidad de la explotación en cualquiera de sus posibles versiones. Tanto puede ser realizada por la simple conexión sincronizada de pesqueros y mercantes, como por vinculación de aquéllos a alguna unidad madre. En el ejemplo español que sirve de eje al presente estudio, ambas soluciones fueron puestas en práctica si bien con independencia entre una y otra.

La flota de "freezer trawler's" había de tener a su servicio aquel número de cargueros frigoríficos que su nivel de actividad exija. Alguno de éstos será congelador para admitir cuando sea necesario carga de pesquero que no lo sea.

El buque madre centralizará las descargas de una flotilla de diez "trawler's" ambivalentes con tanques para conducir el pescado en su medio natural, refrigerado a—2°C. Cuatro unidades irán dotadas de "power-block puretic" para dedicarse a las capturas de superficie, aunque todas resultarán aptas para alternar aquéllas con las de arrastre, demersal o a medias aguas.

No hay experiencia evaluable, hasta el momento, para calcular el índice de productividad relativa de una y otra combinación. Ambas responden a las mismas premisas económicas y completan, por ahora, la estructura del modelo de explotación desarrollado desde base española en el hemisferio antártico. El factor velocidad a plena carga—14-5 nudos en los mercantes y 17 en el buque madre—será preponderante en una y otra operación.[7]

Calidad, aceptabilidad y rentabilidad

La segunda de las deducciones a que antes apuntamos se obtiene en relación a la morfología de la producción física y su aliciente en el mercado. No cabe subestimar este aspecto no operacional del problema si se quiere adquirir del mismo una visión relativamente completa. Poco importaría descubrir en otro hemisferio reservas copiosas y casi intactas de especies marinas accesibles desde bases europeas si transferidas al mercado de destino despertaran insuficiente aceptabilidad.

Para montar un modelo de explotación a base de caladeros ultralejanos, además del índice elevado de concentración es necesario encontrar recursos relativamente valiosos. La rentabilidad depende tanto de la cantidad como de la calidad, pero la apreciación de la última difiere de mercado a mercado. Este principio explica que los langosteros de Bretaña se desplacen hasta las aguas próximas al Nordeste brasileño. No justificaría en cambio, que los "freezer trawler's" de Galicia se desplazasen a Mar del Plata para pescar anchoita o jurel.

Es de presumir que el catálogo de recursos suficientemente concentrados en el habitat de las regiones austro-atlánticas, sea por ahora incompleto. La variedad real irá mostrando sus valores efectivos, a medida que la explotación se intensifique y ensanche. Probablemente, bajo la cortina del desconocimiento eventual, queden grandes masas de peces y crustáceos finos que algún día localizará la investigación empírica o científica.

Mientras tanto hay algunos motivos para sospechar que la expansión pesquera de Europa hacia los antípodas pueda resultar frenada por cortedad de la gama faunística. Nos referimos a especies de alto valor apreciable en este viejo mercado.

Tanto en la región sudeste como en la sudoeste del Atlántico, el recurso ictiológico de mayor masividad es las merluza (*sockfish*). La *capensis* a un lado, a otro la *hubbsi*. Cubren el noventa por ciento del volumen de las copadas en la latitud respectiva. En la composición del diez restante suelen entrar permanentemente el *kinglip* —"congrio colorado"— en Sudamérica, el jurel de gran tamaño, estacionalmente el *smooth* (*macruroplus nigromaculatus*) y pocas especies aprovechables más.

Esta reducida variedad es menos acentuada en las especies de superficie—albacora, otros escómbridos, sardina, anchoa . . .—pero tiene innegable importancia para las pesquerías de arrastre. El área del consumo preferencial de merluza es más restringida que su aerea biológica. En el Japón se desecha. En Norteamérica se subestima. En la Gran Bretaña no tiene especial aprecio. Su campo favorito es Europa meridional y España especialmente.

He ahí otra razón que contribuye a explicar la vinculación a este país de la experiencia austral y su impaciencia por iniciarla. Es notorio que los demás países del mundo pesquero occidental tendrían que partir de otras premisas tanto de naturaleza operacional como de índole mercatológica.

El aparejo como factor económico

De la operación austral en su desarrollo sucesivo se esperan enseñanzas útiles sobre el comportamiento de los artes de pesca. Algunas pueden referirse a la dimensión de la malla en los de arrastre. Otras al uso de los dispositivos que facilitan o accionan la maniobra. Bajo ambos aspectos pueden acusarse en el sur diferencias técnicamente valorables respecto a los mismos procesos en el escenario nórdico.

Volviendo al primer extremo conviene advertir que la dimensión de la malla en una y otra latitud se ajusta a las medidas aprobadas por la Convención de Londres. Han sido calculadas, como es sabido, para proteger la auto-renovación de los recursos bentónicos o filobentónicos, permitiendo la evasión de los ejemplares inmaturos. Esta garantía, internacionalmente respetada,

[7] Se está transformando en buque madre congelador el extrasatlántico de 16,000 tons. "Habana". Tendrá capacidad para congelar y almacenar 4,500 tons, de pescado, transformar una parte en filetes y producir en planta reductora propia 1,500 tons, de harina de pescado por expedición.

asegura la compatibilidad de la explotación más intensa y la densidad de todos los "stocks" vivientes. Incluso podrá estimular el incremento de este último índice, al disminuir la concurrencia trófica de ejemplares tan talludos como voraces, pero ya estériles.

Con independencia del aspecto aquí considerado, donde la concentración es grande y el valor comercial está en relación directa con el tamaño—como en el caso de la merluza—pudiera resultar escasa en el sur la dimensión del mallaje establecido como mínima para el norte. La razón económica, en este caso, puede ir más allá de la razón biológica ya que la ampliación del rombo liberatorio del pez constituye un medio anticipado de selección comercial.

Las mismas circunstancias pueden influir en los resultados de la maniobra del arte por la popa. Es lógico deducir que allí donde la concentración sea baja, el coeficiente de productividad logrado con la rampa o el pórtico basculante resulte relativamente superior al acostumbrado. En tal supuesto, el mayor número de lances por jornada proporcionado por la mecanización de la maniobra puede compensar la eventual flojedad de cada uno.

No ocurrirá lo mismo cuando el volumen de la cosecha sobre la cubierta y su tasa de aprovechamiento para consumo humano, no dependa del número mayor o menor de copadas. Queda excluída la hipótesis del suministro para fabricación de subproductos, ora sea realizado a bordo, ora sea realizado en tierra.

En el primer supuesto, si se trabaja sobre bancos bien poblados y circunstancias atmosféricas normales, el número de lances por día no determinará mayor productividad. Entonces la actividad desplegada por la marinería en la selección y preparación de las piezas, y el ajuste entre este factor y la capacidad de congelación instalada en el buque, parecen ser los elementos condicionantes del nivel de rendimiento efectivo. Donde no operen estos factores, especialmente el último, la rentabilidad de la inversión representada por los dispositivos de maniobra del arte, será sin duda más elevada. Sin embargo, tal apreciación sólo debe considerarse válida cuando la captura se ejecuta con "otter trawl". No en el supuesto de operar en superficie utilizando mecanismos semiautomáticos para halar y largar el aparejo.

También puede la utilidad de aquellos dispositivos resultar realzada al permitir trabajar con mal tiempo como es frecuente en aquellas regiones.

Conclusiones

(i) Sin que el factor biológico deje de mantener su prioridad, en el desarrollo moderno de las pesquerías el factor técnico adquiere papel predominante dando origen a modelos de explotación más arriesgados, en los cuales el principio de la dispersión espacial se contrapone al de la concentración del esfuerzo en las áreas ya intensamente explotadas.

(ii) Los cambios que tal evolución comporta no se limitan a la estructura de los equipos si bien en el buque de pesca, sus artes y la maniobra de ambos, se haga más visible el impacto de la innovación tecnológica. Las aplicaciones de la misma precedieron en algunos países centro-europeos al experimento español que inició la explotación de mares australes, pero sólo el último puso en evidencia la accesibilidad a nuevas fuentes de recursos en plenitud de producción.

(iii) El modelo evolucionado de explotacion presupone la organización de la gran empresa, pero su compatibilidad con la de tipo pequeño y medio se verá favorecida no sólo por la menor gravitación de los costos, especialmente de transferencia, sino por mayor reponibilidad de las poblaciones explotables en proximidad al desviarse una parte del poder de captura hacia caladeros muy lejanos.

(iv) La estructura de la macroempresa responde al incremento de sus dimensiones principales. Este fenómeno engloba el aumento de los costos de financiación, el del nivel de capacitación técnica en el factor humano y el de la asunción del proceso de comercialización en los países no dotados de algún sistema idóneo de distribución de productos congelados.

(v) Para responder a la magnitud de la inversión y el aumento en los demás factores es necesario cuidar la estrategia de la explotación. Dentro de ella en el experimento español se planteó la opción entre el hemisferio norte y sur como espacio operacional resolviéndose a favor de la solución más arriesgada. Esta decisión supuso la apertura de las pesquerías austro-atlánticas desde base europea utilizando flota congeladora para la totalidad de la carga.

(vi) Dada la excepcional longitud de los viajes y sus elevados costos, se advirtió pronto que en la reducción de éstos residia la clave del aumento de productividad. En consecuencia la operación debía orientarse a eliminar días inactivos haciendo uso más prolongado de la superioridad específica del buque congelador sobre el fresquero.

(vii) Tal necesidad económica determinó la introducción de nuevos elementos en el modelo de explotación ligando la flota pescadora, mediante trasbordos, al servicio de buques de transporte frigoríficos. Con fundamento en el mismo principio económico se puso en ejecución un proyecto de buque madre, con flotilla auxiliar de diez unidades pescadoras polivalentes para arrastre y pesca de superficie, dotadas de tanques de agua de mar refrigerada a —2°C. para conducir la pesca.

(viii) Aunque la gama austral de especies marinas no está totalmente conocida, los recursos de relativa concentración en cuanto a especies de fondo se reducen a poco más de la merluza *hubbsi* y la *capensis* cuya aceptabilidad en el mercado español favoreció el experimento. El resultado sería distinto si se destinara a mercados indiferentes o subestimatorios de dicha especie.

(ix) Sobre el comportamiento de los artes de pesca, la operación austral pudiera permitir con fin selectivo la ampliación de las dimensiones de mallaje autorizadas por la Convención de Londres. En cuanto a los dispositivos para facilitar la maniobra del arte, dada la densidad de la biomasa, las limitaciones de rendimiento más pueden proceder de la manipulación previa a la congela-

ción y la capacidad de tratamiento del pescado, que del aumento en el número de copadas en circunstancias normales.

Discussion on Fleet Operations

Mr. G. C. Eddie (U.K.) Rapporteur: Fleet operations are not new, Portugal, Canada and the United Kingdom having in their different ways practised the technique for over 300 years. But under modern conditions it has revived and developed to meet special needs with particular concentration on motherships although in some instances bigger trawlers with enlarged storage accommodation would seem to meet the same needs.

While the Japanese in some cases are using merchantmen for transporting fish from distant bases, that system has not found favour in British thinking for three reasons—the availability of cargo space in the right place at the right time, the cost of transfer, and the small amount of low temperature refrigeration space available.

While mothership operations give greater fishing time, this was partly offset by the cost of the mothership unless adequately compensated for by smaller and simpler catchers. This called for study.

The requirement for daily delivery to the mothership of some species was dictated by the need for quality, thus lifting the subject into the realm of fish processing technology, rather than of gear. In the transfer of catches, the Germans found that redfish could be transferred successfully through detachable codends even after several hours' immersion, but the British found that the quality of cod was noticeably poorer even after half an hour's immersion and of gutted cod, after a few minutes.

The British, in their experiments, found no difficulty in transferring catches between trawlers by various methods in at least up to force six winds. The Japanese papers describe their transfer procedure in both "fine" weather and "rough" but it would help understanding if the definition of these terms could be given in the Beaufort scale of wind strength and sea state. Pictures of Japanese "rough" conditions did not seem very rough by North Atlantic standards.

Their papers showed that successful fleet operations required a complete exchange of information between the catchers so that each was working for all. I think the Western Europeans have something to learn here and I congratulate our Japanese friends for the considerable contribution they have made to the Congress by their papers.

While the motherships have their place it is noteworthy that European nations, including the Russians, have tended to use independent freezing trawlers and factory trawlers rather than motherships. It would be interesting to have more detail of economic information in justification of motherships and in particular as to whether with modern propulsion equipment, much large, independent vessels freezing their own catch were not possible. Directions from motherships lead to greater efficiency in many cases; since the best British distant water trawlers caught up to three times as much as the poorest improvement by direction might be as effective and easier to achieve than improvements in the gear itself.

Mr. V. Paz-Andrade (Spain): The Spanish experiment in conducting fleet operations in South American and South African waters represents a technological effort within a framework of costs. The provision of all refinements had to be reflected in increased production. We also had to consider size in relation to economy. We first considered the construction of our freezer ships with a capacity of 250 to 300 tons and two further ships with a load capacity of 350 to 400 tons and two further sterntrawlers with a capacity of 1,000 tons each. For 20 months the eight ships have been in commission; and we have experience of the operation of the first six of these units. But as these experiments have developed, in spite of the short term concerned, we have seen that the ships have to move over distances of 5,000 miles and we have found that it would be more profitable to introduce freezer transport under the conditions described by the rapporteur rather than receive the catches direct at home ports from the fishing ships. Thereby it was possible to increase the time spent by the ships on the grounds and that will increase the flow of fish.

The second part of the programme consisted in the building of a factory and mothership. This is planned by the conversion of an ex-passenger liner of 15,000 tons. This ship in association with the fleet of 10 auxiliary ships will be versatile and highly developed. Naturally, their operations will include the lessons which have been learned from the Japanese experiences with motherships. The factoryship will have capacity for 5,000 tons of frozen fish, 2,000 tons of fish meal (processed aboard) and about 500 tons of frozen fillets. The fleet will be made up by 10 auxiliary ships which can be used for trawling and either line fishing or seining. Four of these ships will be equipped for handling gear and almost all of them will have refrigerated salt-water tanks. Naturally we do not have the experience yet concerning these items which are still under construction but we think this unit made up of a mothership and 10 fishing ships will provide us with a very profitable operation in spite of the very high investment. This whole venture is a result of private enterprise and is operated without any subsidy.

The ships are fitted with comfortable accommodation suited for all problems that may arise. The accommodation gives the crew, in addition to high wages, all the necessary comforts they need and which it is possible for the firm to provide.

The Spanish experiment may provide one or two lessons on the possibility of opening up these new grounds for providing more vital food. The species actually caught so far consist mainly of hake and whiting for which there is much demand in Spain. That could be a limiting factor from the marketing point of view for countries which do not like that type of fish. Generally speaking they felt that in this long-range fishing enterprise they were exploring an attractive field which made a dual contribution to the fishing economy of the world. It would relieve those fishing grounds which have been worked over, possibly to exhaustion, and would enrich those sources which are available by increasing the profitability of new grounds. They felt that they were helping Europe in this way.

Dr. Miyazaki (Japan): I can give a general idea of the Japanese fleet operations. The first is that because of the long distances that have to be covered in our fishing operations for tuna, salmon and crab, the industry has to rely considerably upon motherships and the concentration of the catch from each catcher and by processing it immediately on the mothership. By this method, the total tonnage of the catch during the season has been considerably increased: in the case of salmon to 53,000, with tuna to 221,000 and even in crab trawling they have achieved a total tonnage of something like 3,000 in a season. A second point of value is that

very good directives can be given by the mothership to minimise inefficiency that might be caused by disorderly fishing. During the off-season the motherships are normally used as cargo carriers while the catchers are used in other operations. The tonnage of motherships in tuna fishing is something like 4,000 and there are normally five catchers of something like 100 tons each.

Mr. Eddie, summing up, said the supplementary contribution to Spanish thinking was important and it emphasises how fishing was governed by economics and that they varied between country and country. The additional information from Japan about fleet operations was valuable as justification for the use of motherships and their contribution to the greater efficiency of the fleet.

Commander M. B. F. Ranken (U.K.): wrote that he was concerned at the lack of accurate information on average and maximum catching rates by different methods of fishing and on different fishing grounds throughout the world. Most information given by vessel owners or skippers was based on hearsay or on very good days and tended to be grossly inflated—real fishermen's tall tales! Also lacking was information on average and maximum fish sizes, weights and thicknesses on the various grounds; in many cases the exact varieties caught were uncertain due to the wide variation in names for identical or similar fish over quite a small area. Cases were known where the names varied from village to village.

When planning the size of fishing vessels and the equipment to be provided for catching and processing, it was essential to have accurate information on catching rates as well as on fish sizes and variety. This information was even more essential when planning fleet operations since they affected not only the factory/mothership but also the number and type of catchers, the logistic support required and many other aspects, technical, commercial and economic.

A Fishing Gear Congress seemed to him to be a logical occasion on which to make a plea for accurate statistical information on these and related subjects to be collected and correlated under the auspices of FAO. He hoped that this work could be put in hand with the help of delegates to the Congress and others. It was also important that it should be kept up to date as conditions or methods changed in particular fisheries both large and small.

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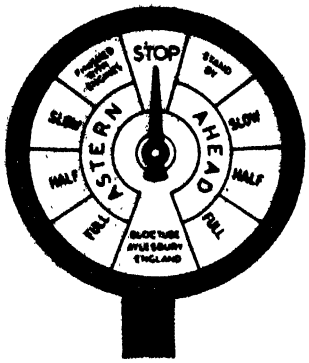

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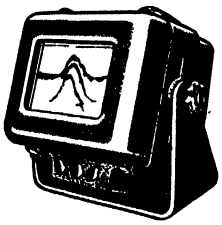

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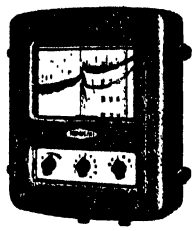

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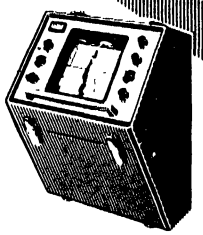

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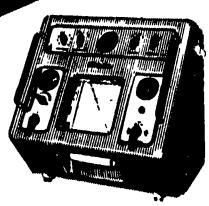

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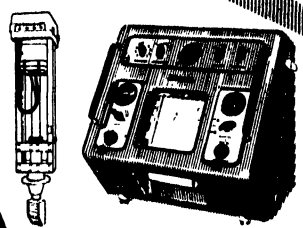

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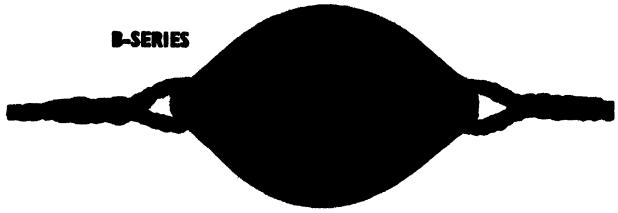

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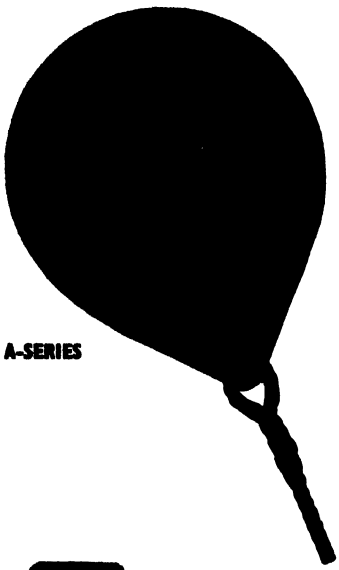

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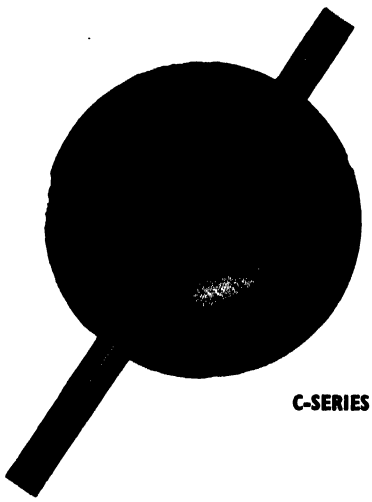

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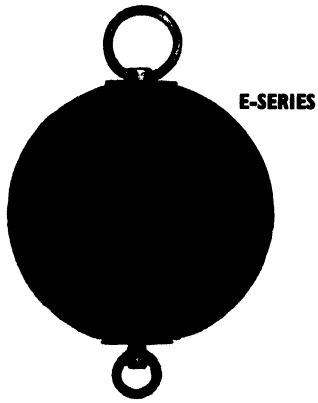

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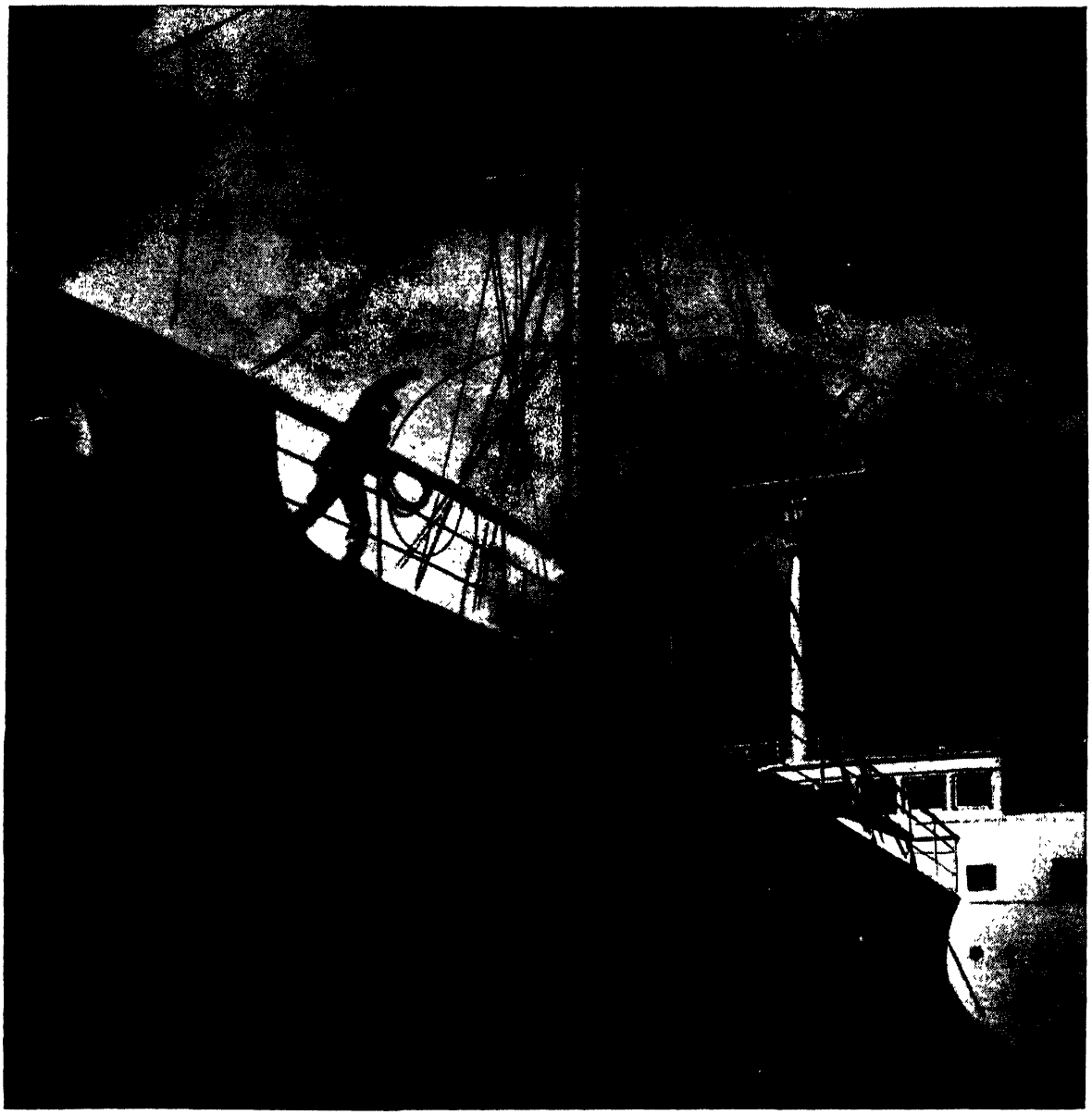

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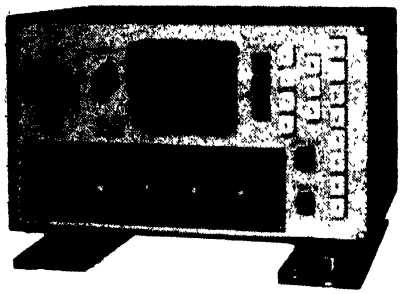

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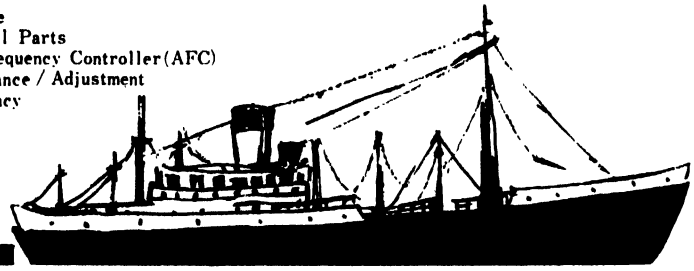

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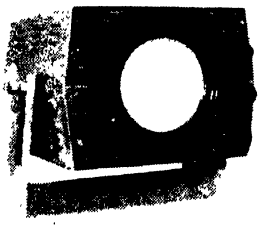

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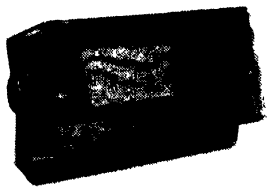

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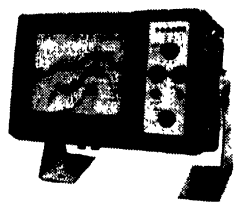

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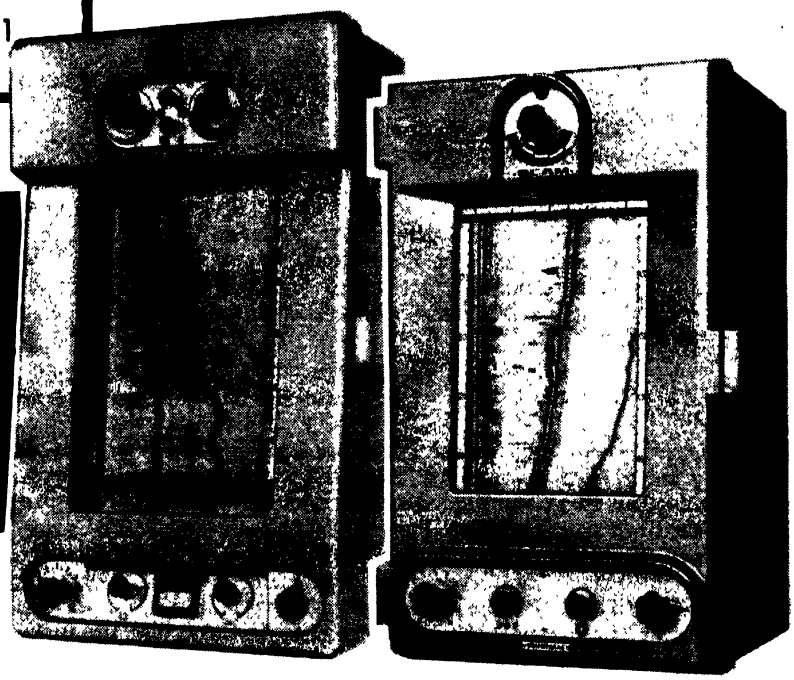

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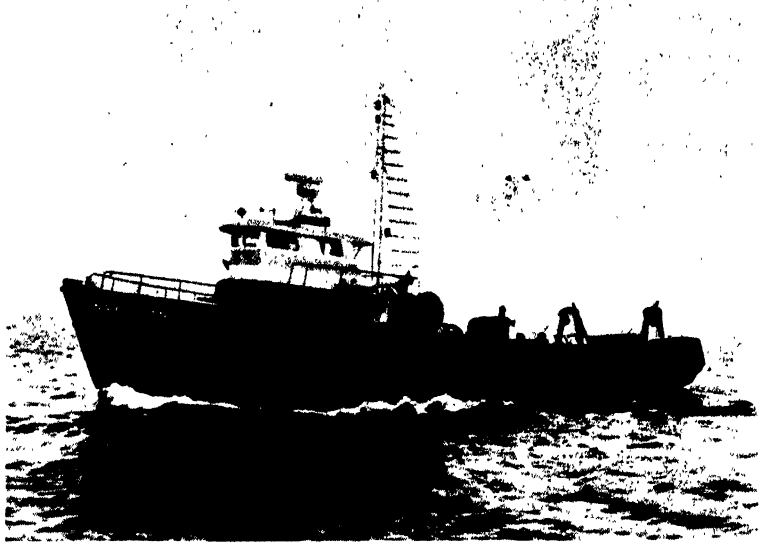

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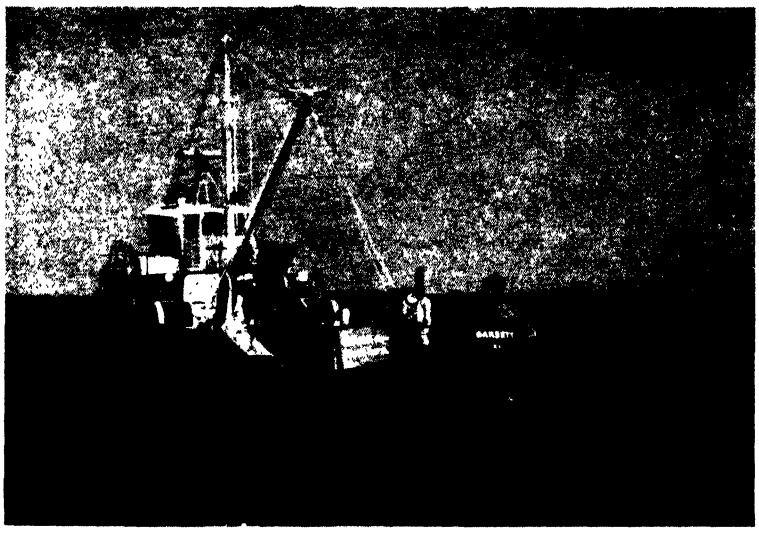

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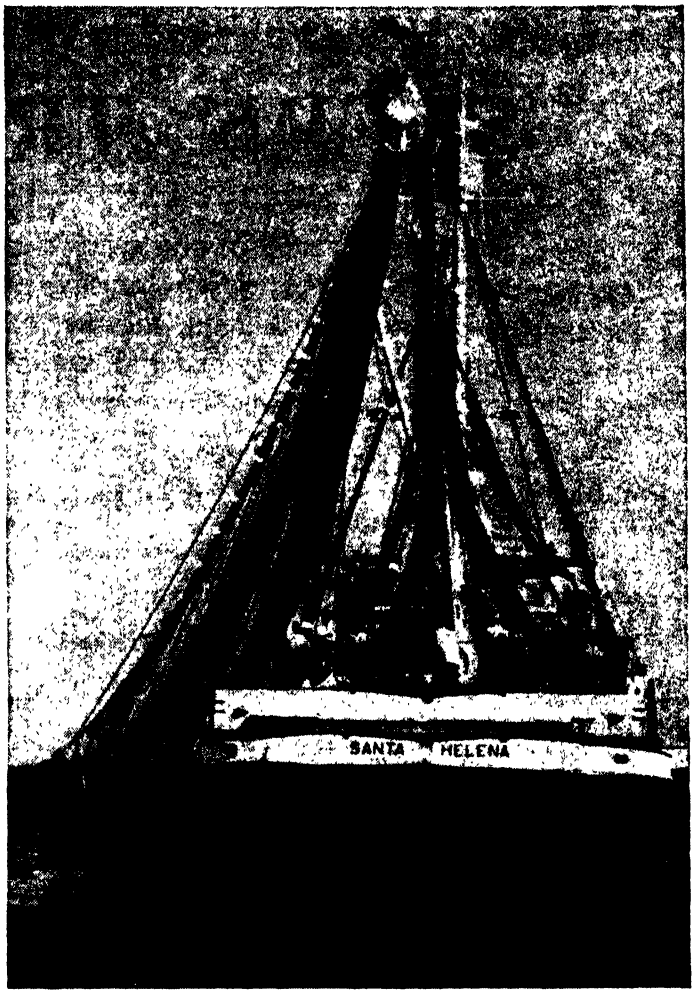

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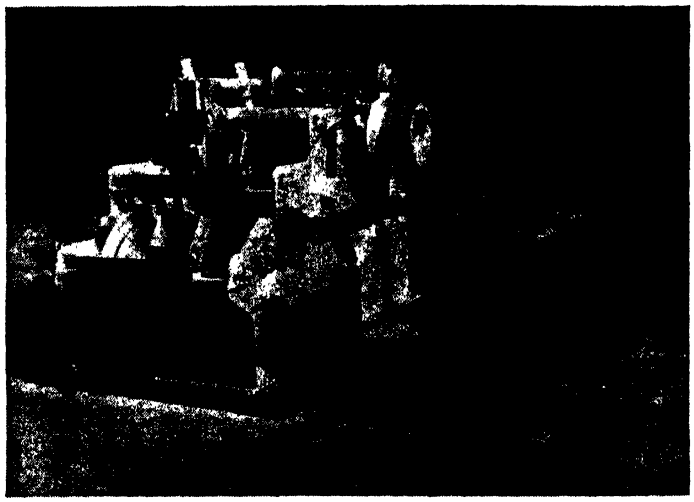

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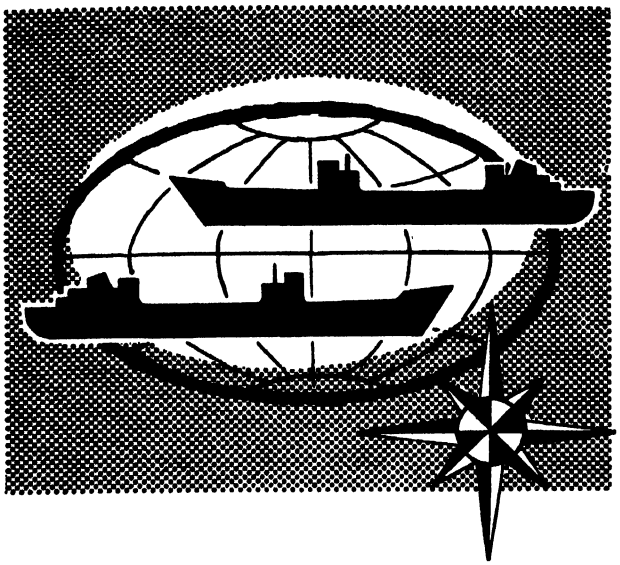

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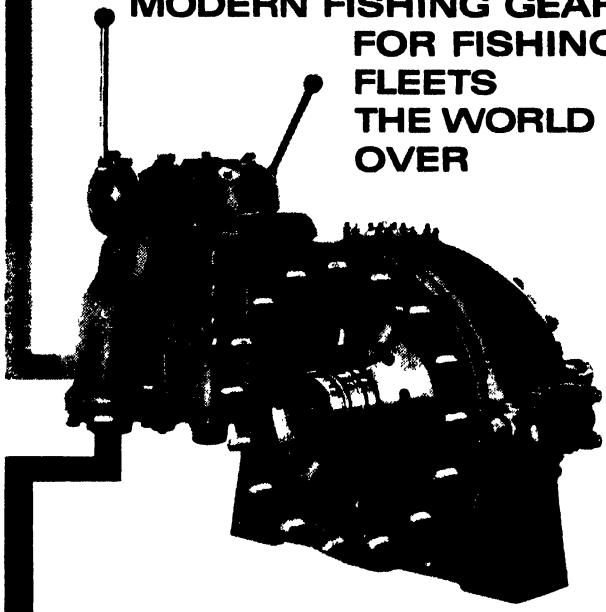

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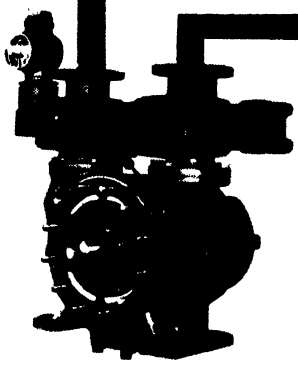

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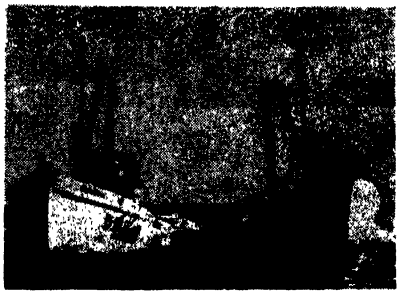

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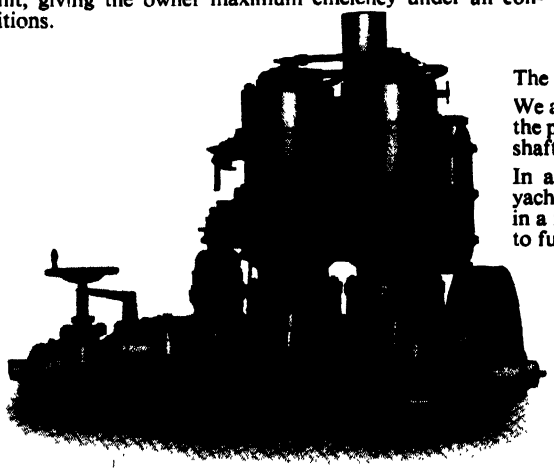

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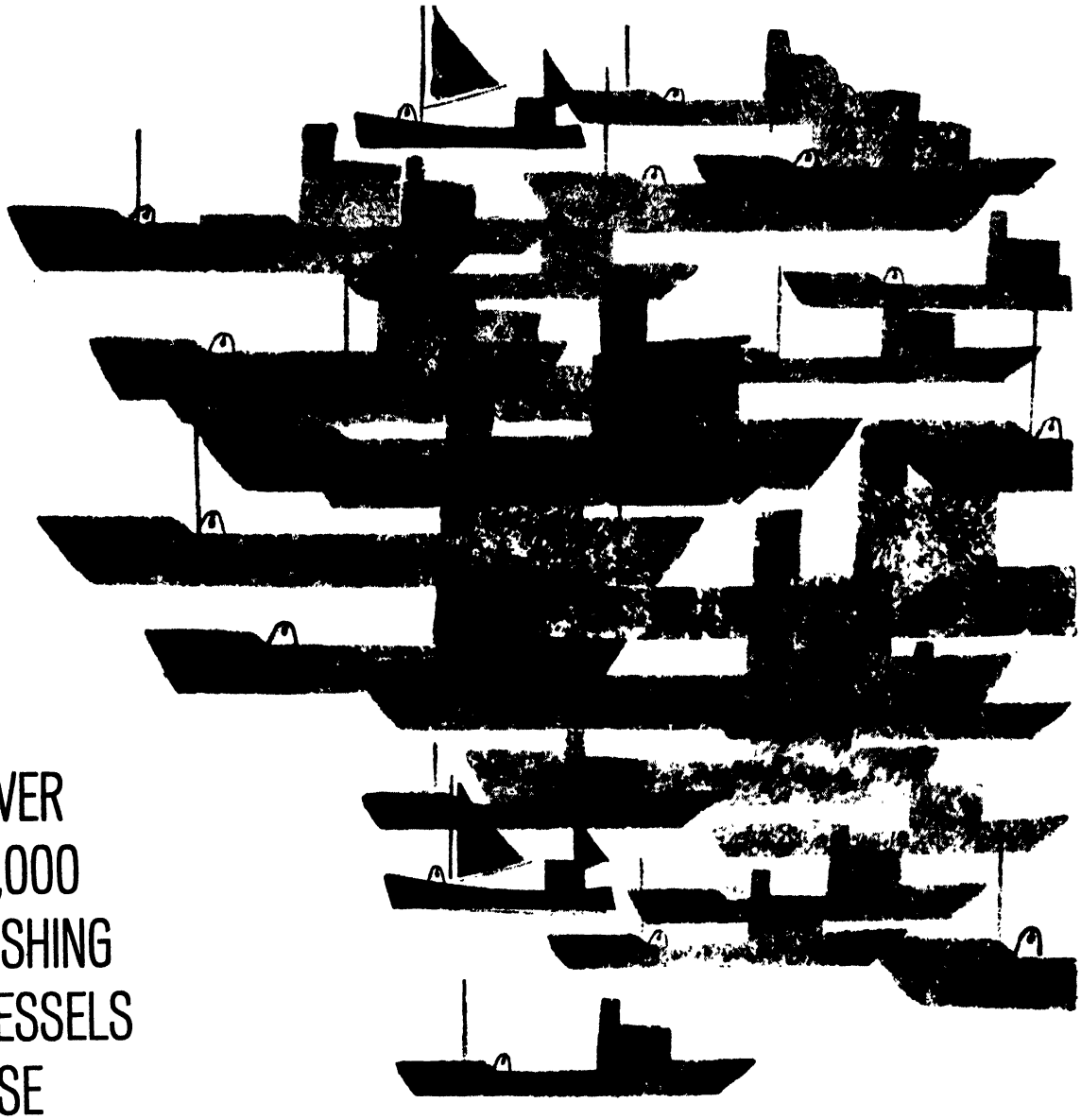

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The Theory of Designing and Testing Fishing Nets in Model

Abstract
The paper describes the theory of model experiments and gear construction and is meant for those fisheries specialists who are not familiar with the mechanical and mathematical theories involved. Once the basic fishing method has been decided on, in accordance with the commercial scale of the industry, the fishing ground and other physical and economical factors, the design of the gear can be undertaken. Based on knowledge of these factors the net design, the shape and tension distribution can be predicted by analytical methods. However, due to the difficulty of obtaining exact information on the operational conditions, the net designer normally works from rough estimations and it is therefore often an advantage to test the design in model form. Such model tests can only be successful in so far as the conditions assumed when applying the modelling laws were correctly estimated.

The paper describes in an easily understood manner the calculation of the weight, resistance and shape of netting in water as a first step in analytical gear design. The mechanical similarity between full scale and model nets are then explained according to the laws developed by Prof. M. Tauti (1934).

Tauti's laws, however, do not include suitable modelling laws for ropes and certain auxiliary gear. The author worked out mechanical similarity rules covering ropes, floats and sinkers used in fishing nets, and provides mathematical explanations of these rules.

The paper furthermore leads on to equations for calculating the parameters of large nets from smaller prototypes.

In the past, almost all fishing gear has been evolved entirely by trial and error but in the last few years a small beginning has been made towards supplementing the empirical approach by mathematical calculations. As yet, we have only a very incomplete knowledge of many of the complex factors involved. However, thanks to recent technological advances, we are learning more about the behaviour of fishing gear underwater and the reaction of fish to it, and the challenge is to continue our research towards developing the general principles of analytical gear design.

Dessins de filets et epreuves de leurs modèles réduits

Résumé
La présente étude qui décrit la théorie des modèles réduits et la construction d'engins de pêche est destinée aux techniciens qui n'ont pas de connaissances mathématiques et mécaniques approfondies.

Pour projeter le dessin d'un engin de pêche il faut, partant de la méthode de base qui sera appliquée, tenir compte de l'importance de l'industrie, des lieux de pêche et autres facteurs physiques et économiques. Connaissant ces facteurs, il est possible de prévoir par des méthodes analytiques, le dessin du filet, ses formes et la distribution des tensions. Cependant, les conditions-mêmes de l'opération étant difficilement prévisibles, il est toujours préférable de faire des épreuves avec des modèles réduits. Ces épreuves seront d'autant plus satisfaisantes que les conditions d'opérations auront été estimées justement.

L'étude décrit clairement la façon de calculer, d'après les moyens analytiques, le poids, la résistance et la forme que le filet prend dans l'eau. La similitude mécanique entre l'engin en vraie grandeur et son modèle est expliquée suivant les lois développées par le Professeur M. Tauti (1934). Mais ces lois ne s'appliquant pas aux cordages ou aux engins auxiliaires, l'auteur a élaboré des lois de similarité mécanique pour les cordes, flotteurs, plombs utilisés dans la construction d'engins de pêche et donne l'explication de ces lois.

Dans cette étude également sont données les formules nécessaires pour calculer les paramètres d'un grand filet en partant des mesures de la maquette.

L'ancienne méthode de tâtonnements utilisée pour la fabrication des filets a récemment fait place à une méthode plus mathématique bien que certains facteurs très complexes de ce problème soient encore mal connus. Plus récemment encore, les recherches concernant le comportement d'engins de pêche en action et la réaction des poissons vis-à-vis de ces engins ont fait de grands progrès et nous nous sommes rapprochés du but qui consiste à développer les principes généraux concernant le dessin analytique des engins de pêche.

by
Tasae Kawakami

Department of Fisheries, Kyoto University

La teoria del proyecto de artes de pesca y del ensayo de sus modelos

Extracto
Describe el autor la teoría de la construcción y los experimentos con modelos de artes de pesca; se dirige a los especialistas pesqueros que no están familiarizados con las teorías mecánicas y matemáticas que entran en juego. Una vez que se ha decidido el método de pesca fundamental de acuerdo con la importancia comercial de la industria, el caladero y otros factores físicos y económicos, se comienza el proyecto de los artes. Basándose en el conocimiento de dichos factores, la forma y distribución de la tensión de la red puede predecirse por métodos analíticos, aunque debido a la dificultad de obtener información exacta sobre las condiciones de trabajo, el proyectista parte de estimaciones aproximadas por lo que puede convenir ensayar un modelo del proyecto. Estos ensayos solamente pueden dar resultados satisfactorios si al aplicar las leyes de modelismo se acierta en las suposiciones de las condiciones reales.

El autor describe de manera fácil de comprender el cálculo del peso, de la resistencia y de la forma de la red en el agua como un primer paso en el proyecto de redes analítico. A continuación la similitud mecánica entre los modelos y la red a toda escala se explican según las leyes del Prof. M. Tauti (1934). Sin embargo, estas leyes no comprenden las relativas a cables y cierto material accesorio. El autor formuló leyes de similitud mecánica que comprenden cables, flotadores y plomos empleados en las redes de pesca y da explicaciones matemáticas de estas leyes; menciona también ecuaciones para calcular los parámetros de redes grandes a partir de prototipos pequeños.

En el pasado casi todo el material de pesca se ha construído siguiendo métodos de tanteo, pero en los últimos años se ha comenzado a complementar el enfoque empírico con cálculos matemáticos. Todavía tenemos conocimientos muy incompletos de los muchos y muy complejos factores que entran en juego, pero gracias a los recientes adelantos técnicos se va conociendo mejor el comportamiento del material de pesca en el agua y las reacciones de los peces ante él, lo que estimula a continuar las investigaciones para formular los principios generales del proyecto analítico de los artes.

1. INTRODUCTION

THIS paper aims to describe the theory of model experiments for fishing gear specialists who may not be completely familiar with mechanical and mathematical theory. A special attempt will be made to discuss these theories on the basis of elementary mechanics.

To devise new fishing methods or improve old ones, one must first study fish behaviour and environment.

Despite modern echo sounders, underwater cameras and other aids, these studies are still relatively new and difficult and the net designer must often work from incomplete biological data.

Next compare fishing methods and choose the basic method which best fits commercial factors, type of fleet operation, fishing ground location and other essential factors.

Gear designing begins only when this fundamental method has been chosen. It begins with accumulation and analysis of previous data. Dr. Terada and co-workers were among the first to test the resistance of plane netting towed through water. Since then, there has been much experimental and theoretical work on fishing gear mechanics.

Tauti's law on the hydrodynamic resistance of netting and his model theory are based on these assumptions:

(a) that the elongation of the netting twine is negligible,
(b) that the netting twines are perfectly flexible,
(c) that Newton's law of hydrodynamic resistance is valid for every portion of the net, irrespective of its Reynolds' number, and
(d) that any change in the form of the net occurs so slowly that the external forces acting on each element of the net can be considered to be in quasi-equilibrium.

Recently the writer added some extensions to the modelling law for ropes in the nets and for cases in which inertia cannot be neglected because of accelerated motion caused by surface waves.

If net design details and operating conditions are given, the shape, attitude, and tension distribution can be predicted by analytical methods, with no need for physical testing. The author and co-workers have found this analytical treatment of some practical value for trawl nets. The difficulty is that, because we must find a set of solutions by solving simultaneous equations involving transcendental functions, the numerical computations needed to solve the equations for the analysis are long and tedious. A further difficulty is that the exact operation conditions of the fishing ground can seldom be determined. This means that the net designer must work from a rough estimation of the total situation. Because of this, it is an advantage to be able to test designs in model.

Some doubts have been expressed on the practical value of testing fishing nets in model. These model tests depend on the accuracy of the modelling law and will be successful only in so far as conditions assumed in the modelling law are fulfilled. Test effectiveness also depends on strict observance of certain rules.

One of these is to ensure, as far as possible, mechanical and geometrical similarity between the full-size net and its model. Even if all conditions are properly satisfied, the mechanics and geometry of the full-size net may not be identical. These differences must be expected and allowances made for them.

Because the modelling law itself is imperfect and its conditions are difficult to comply with exactly, the fidelity of model experiments is limited. Thus, the next steps are to correct design faults noticed in the model tests, build the gear to full scale and test it under operating conditions. This final test is necessary, not only because of model limitations, but also because we may be ignorant of true operating conditions such as waves, sea bottom or underwater currents. It is often impossible to duplicate such conditions in model tests.

Modern gear tests demand sturdy and reliable underwater instruments with self-recording or telemetry appliances.

2. NET STRUCTURE

The mesh is the smallest unit of a fishing net. A mesh is a rhombic opening enclosed by four bars of twine of equal length firmly knotted at the four corners. Fig. 1 shows how one bar is related to two meshes, how one knot is related to four meshes and how two bars and one knot are the basic elements of mesh structure. This last point is seen clearly if one considers that in weaving a net by hand, one mesh is completed by making two bars and one knot.

Although a good net is flexible, it resists over-stretching. The net can be made to take any form but, in doing so, cannot exceed the total length of the individual bars. Thus the net shape changes in accordance with the distribution of external forces acting upon it. This makes accurate knowledge of these forces imperative.

The area of a single mesh can be changed by hanging or mounting the webbing to the frame line, i.e., by changing the angle between two adjacent bars to achieve a more "open" or more "closed" mesh. The mesh opening can be expressed by this angle, φ, as shown in Fig. 1.

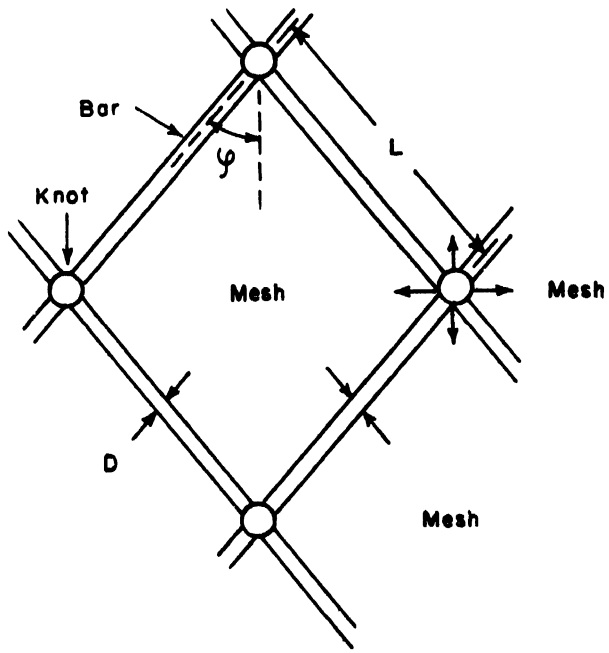

Fig. 1. Construction of mesh.

If L is the length of a bar, the mesh area A is given by:

$$A = L^2 \sin 2\varphi \tag{1}$$

A stretched piece of netting may be considered as a continuous and homogeneous membrane (through which water can pass like a sieve) if the differences in physical state between neighbouring meshes are negligible. In actual conditions, this membrane of netting will be subjected to two kinds of external forces, i.e., the hydrodynamic force due to the current and the apparent weight in water. When the change of motion of the net occurs so slowly that the inertia force can be neglected, these two kinds of external force will be in a balanced state against the tension in the netting. In the following two sections we shall be concerned with these two kinds of external forces.

3. APPARENT WEIGHT OF THE NET IN WATER (Iitaka 1958)

The apparent weight of a body in water is given by the difference between gravity and buoyancy, and is obtained by multiplying the density difference between the body and the volume of the water the body displaces. Let D be the diameter of twine, L be the length of the bar of mesh, $(l—p)$ be the porosity of twine. With regard to the knot, let l be the length of twine allotted to one knot. (As the twine is tightened in some measure at the knot, the diameter, D^*, and the porosity, $(l—p^*)$, of the twine may be somewhat smaller at the knot than at the bar.) Then the apparent weight, W, of one mesh (i.e., two bars and one knot) is given by:

$$W = [2\pi\left(\frac{D}{2}\right)^2 Lp + \pi\left(\frac{D^*}{2}\right)^2 lp^*](\rho - \rho_w), \tag{2}$$

where ρ and ρ_w are the densities of the fibre and water, respectively. Since the density of the fibre or filament of the twine itself is considered to be unaltered by tightening the knot, then:

$$\pi\left(\frac{D}{2}\right)^2 p = \pi\left(\frac{D^*}{2}\right)^2 p^*, \text{ or } D^* = D\sqrt{\frac{p}{p^*}}. \tag{3}$$

A knot is simply two pieces of twine twisted and tied together. Therefore, if the knots are the same type, the length l may be directly proportional to the circumference or to the diameter of the twine:

$$l = kD^* = kD\sqrt{\frac{p}{p^*}}, \tag{4}$$

where k is a constant depending upon the type of knot. Thus we have:

$$W = 2\pi\left(\frac{D}{2}\right)^2 p\,[L + \frac{k}{2}\sqrt{\frac{p}{p^*}}\,D](\rho - \rho_w). \tag{5}$$

Dividing this expression by the area of mesh, we obtain the apparent weight of netting in water per unit area:

$$w = \frac{W}{A} = \frac{\pi p}{2 \sin 2\varphi}\left[\left(\frac{D}{L}\right) + \frac{k}{2}\sqrt{\frac{p}{p^*}}\left(\frac{D}{L}\right)^2\right] D(\rho - \rho_w). \tag{6}$$

This equation can be expressed, by uniting constants, in the form:

$$w = f(\varphi)\left[\left(\frac{D}{L}\right) + a\left(\frac{D}{L}\right)^2\right] D(\rho - \rho_w), \tag{7}$$

where $f(\varphi) = \pi p/(2 \sin 2\varphi)$ is a constant depending on the degree of slackness of the netting, and $a = (k/2)\sqrt{p/p^*}$ is also a constant depending on the type of knot and its tightness.

4. THE RESISTANCE OF THE NET IN A CURRENT

When any solid body of a given shape is placed in a certain position relative to a uniform current of any fluid, a hydrodynamic force is exerted upon that body. The magnitude of this force depends mainly on the density ρ_w of the fluid, the relative velocity, v, of the body to the fluid, and the projected area, S, of the body to the plane normal to the current. These quantities can be combined in a unique form $\rho_w v^2 S$ to give the dimensions of a force. The parallel component of this force to the current is commonly called resistance and is expressed as:

$$F = C_D \frac{\rho_w v^2 S}{2} = bv^2 S, \tag{8}$$

where C_D, and thus b, is a constant coefficient of resistance depending mainly on the shape and attitude of the body, if the fluid is water. Strictly speaking, the value of C_D is not constant, but varies depending on the Reynolds' number, R_e, of the flow. Reynolds' number is a function of the form:

$$R_e = \frac{lv}{\nu} \tag{9}$$

where l is the typical length of the body and ν is the kinematic viscosity of the fluid. However, according to experimental results on fishing nets, it has been found that we can put C_D, and thus b, as constant for a rather wide range of the Reynolds' number, i.e., we can assume that the resistance varies proportionally with the square of current velocity for practical purposes. This resistance law was first proposed by Newton, and holds pretty well for motions where the resistance is due to current inertia. Thus, hereafter, we shall use the equation (8) as the resistance law of the fishing net.

Now we proceed to estimate theoretically the resistance of a mesh of netting set perpendicularly to the current. To this end it is sufficient to calculate the resistances of two bars and one knot.

Since the projected area of two bars is $2LD$, their resistance will be of the form:

$$b(2LD)v^2. \tag{10}$$

The projected area of a knot is considered to be proportional to two-thirds power of its volume. On the other hand, the volume of a knot must be proportional to the volume of twine used to tie the knot, and this is given by:

$$l\pi\left(\frac{D^*}{2}\right)^2 = \pi k\left(\frac{p}{p^*}\right)^{3/2}\left(\frac{D^3}{4}\right). \tag{11}$$

Thus the resistance of a knot will be of the form:

$$c\left[\pi k\left(\frac{p}{p^*}\right)^{3/2}\left(\frac{D^3}{4}\right)\right]^{2/3}v^2 = b^*D^2v^2, \tag{12}$$

where c is a proportional constant depending upon the type of knot and b^* is also a constant depending not only upon the type of knot, but also its tightness. Thus we can obtain the resistance per unit area of webbing by dividing the sum of these resistances by the area of one mesh as follows:

$$r_{\theta=90} = \frac{[2bLD + b^*D^2]v^2}{L^2 \sin 2\varphi} = \frac{2b}{\sin 2\varphi}\left[\left(\frac{D}{L}\right) + \frac{b^*}{2b}\left(\frac{D}{L}\right)^2\right]v^2. \tag{13}$$

Next, in the case where the netting is supported parallel to the current, the projected area of the bars may be reduced to $2LD \sin\varphi$, and the constant b^* in the above expression may change to some other analogous value b^{**}, according to the type of knot. Then the resistance acting per unit area of webbing may be given by:

$$r_{\theta=0} = \frac{2b \sin\varphi}{\sin 2\varphi}\left[\left(\frac{D}{L}\right) + \frac{b^{**}}{2b \sin\varphi}\left(\frac{D}{L}\right)^2\right]v^2. \tag{14}$$

When the netting is inclined to the current at an angle θ, it may be clear, from the analogical inference, that the resistance may be represented by the form:

$$r = g(\varphi, \theta)\left[\left(\frac{D}{L}\right) + h(\varphi, \theta)\left(\frac{D}{L}\right)^2\right]v^2, \tag{15}$$

where g and h denote definite functions of angles φ and θ.

5. MECHANICAL SIMILARITY OF FISHING NETS (Tauti 1934)

We now consider the static situation, in which the forces acting on a segment of netting are in equilibrium, when the net segment moves through water at a constant velocity or, conversely, the net remains at rest and current of a constant velocity flows through it. This situation is said to be in equilibrium under the actions of the three forces: apparent gravity, current resistance, and the tension in the webbing. Owing to the fundamental law of mechanics, if a particle is in equilibrium, the resultant force acting upon the particle must be zero, compensating mutually. Let A be the area of an element of the net and S its circumference, and T be the tension in the webbing. Then the vectors of these forces, wA, rA and TS must complete a closed polygon, in this case a triangle, as shown in Fig. 2. This condition will hold approximately

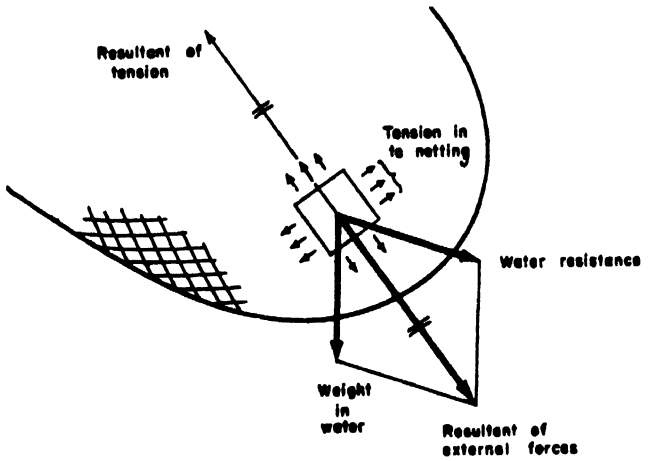

Fig. 2. Equilibrium of forces in the netting.

true for the case in which the motion of netting has some acceleration, because the mass of netting is usually very small, so that the inertia force cannot grow as large as the other forces. This is called quasi-equilibrium.

Consider two nets of different size but of similar design, of which one is the full-scale net and the other is its model, and distinguish the notations of model net from that of full scale by putting a prime sign (′) after the corresponding notations. Under what conditions will these nets have a similar geometric configuration and a similar attitude? The configuration and attitude of a net must be completely determined merely by the external forces acting upon them, if the net materials are perfectly flexible and the state of the net remains unchanged. Therefore, the answer to the above question evidently is that forces acting on corresponding parts of the two nets bear the same ratio to each. The relations which satisfy these conditions make up the law of mechanical similarity, and are indeed the modelling law which we are seeking, i.e., the two nets should be geometrically similar.

To begin with, suppose both nets are divided into components in such a manner that corresponding to any part of the full-scale net there is a geometrically similar part in the model net. If we continue this equal division until we have a large number of very small parts, any single divided part can be considered as a flat plane or an element of netting membrane. We now focus attention on a set of these small parts in a given area of one net and locate corresponding elements in the other net.

If the webbings of the two nets are hung to the framing with an equal ratio of shortening, it is clear, for a geometrically similar configuration, that the meshes of the corresponding parts will open similarly (i.e., to the same degree) irrespective of the mesh size, i.e.,

$$\varphi = \varphi' . \tag{16}$$

Since we assumed that the corresponding parts of both nets take similar attitudes against the current, we can put:

$$\theta = \theta' . \tag{17}$$

When the model net takes the same shape as the full-scale net, the triangles of force vectors must be geometrically similar for corresponding parts of both nets. That is, the corresponding angles must be equal and the three sides of the triangle are in proportion (Fig. 3).

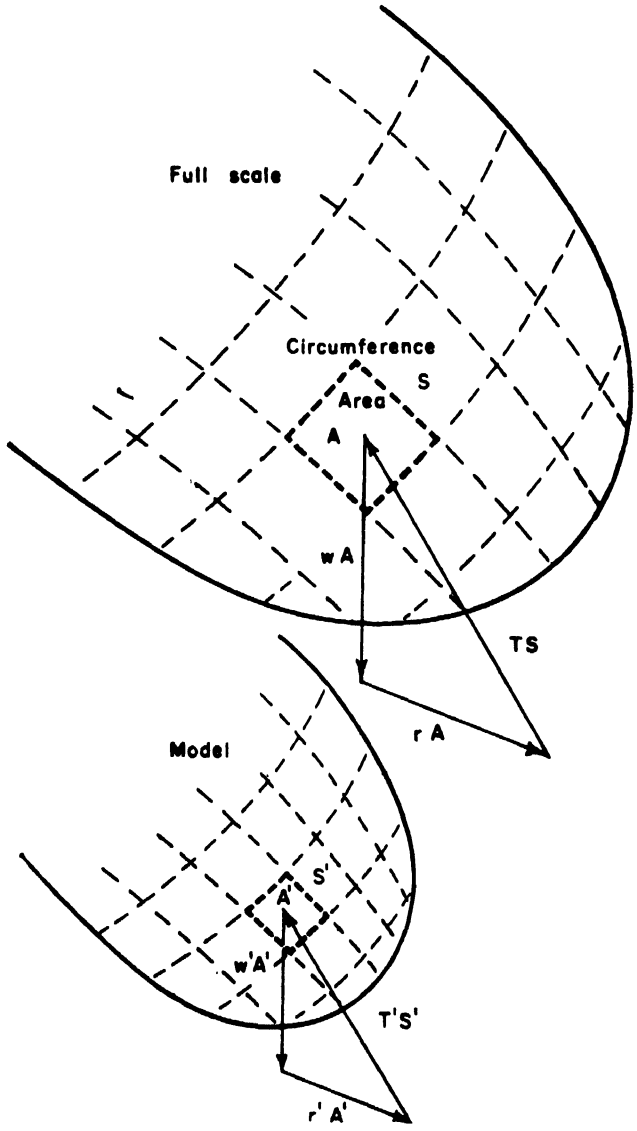

Fig. 3. Mechanical and geometrical similarity between full scale and model.

Then the condition mentioned above is expressed by:

$$\frac{w'A'}{wA} = \frac{r'A'}{rA} = \frac{T'S'}{TS} = \frac{F'}{F} \tag{18}$$

where F denotes the total force exerted by or acting on the net. It may be needless to say that A and S are proportional to the total area and the linear size of the net, respectively, and the total area is proportional to the square of the linear size, λ, of the net; then we may write:

$$\frac{A'}{A} = \frac{\lambda'^2}{\lambda^2}, \quad \frac{S'}{S} = \frac{\lambda'}{\lambda} \tag{19}$$

When both nets are the same shape, i.e., $\varphi=\varphi'$, $\theta=\theta'$, and if the knots of both nets are the same type, it follows that $a=a'$, $f=f'$, $g=g'$, and $h=h'$, where a is a constant depending upon the type of knot and f, g and h are definite functions of φ and θ as appeared in equations (7) and (15). Thus we have from equation (18):

$$\frac{\lambda'^2[(D'/L') + a(D'/L')^2]D'(\rho' - \rho_w)}{\lambda^2[(D/L) + a(D/L)^2]D(\rho - \rho_w)} = \frac{\lambda'^2[(D'/L') + h(D'/L')^2]v'^2}{\lambda^2[(D/L) + h(D/L)^2]v^2} = \frac{\lambda'T'}{\lambda T} = \frac{F'}{F} \tag{20}$$

Now, if the netting of the model has been woven so as to satisfy the next relationship:

$$\frac{D}{L} = \frac{D'}{L'}, \tag{21}$$

the factors in the bracket in equation (20) would be reduced, with this result:

$$\frac{\lambda'^2 D'(\rho' - \rho_w)}{\lambda^2 D(\rho - \rho_w)} = \frac{\lambda'^2 v'^2}{\lambda^2 v^2} = \frac{\lambda' T'}{\lambda T} = \frac{F'}{F}. \tag{22}$$

Then if we arbitrarily chose the following two ratios, Λ and V^2:

$$\Lambda \equiv \frac{\lambda'}{\lambda}, \qquad V^2 \equiv \frac{D'(\rho' - \rho_w)}{D(\rho - \rho_w)}, \tag{23}$$

we have, from equation (22),

$$\frac{v'}{v} = V, \qquad \frac{T'}{T} = \Lambda V^2, \qquad \frac{F'}{F} = \Lambda^2 V^2. \tag{24}$$

The equations (16), (17), (21), (23) and (24) are the fundamental criteria for mechanical similarity of the fishing net. Expression (24) should be satisfied throughout the whole net according to equation (18); while equation (21) holds adequately only for similarly situated portions in both nets, because this condition has been introduced to reduce the fraction in equation (20). Notice that equations (21) and (23) give the conditions to be satisfied by the webbing; equations (16) and (23) give the rule to be obeyed in designing and tailoring the model net; equation (24) shows the relations which will be established in the operation; and equation (17) with equation (23), is a mathematical representation of geometrical similarity between the full-scale net and its model.

The above results can be summarised, in order of practical procedure, as follows:

(a) First, define the reduction ratio, Λ, of the model as large as the circumstances permit; i.e., put:

$$\frac{\lambda'}{\lambda} \equiv \Lambda \tag{25}$$

Each part of the webbings and frame lines should be reduced in length according to this ratio. It is desirable that this ratio be larger than 1/20.

(b) Next, determine the twine diameter, D, and its density, ρ, such that the ratio:

$$\frac{D'}{D}\,\frac{\rho' - \rho_w}{\rho - \rho_w} \equiv V^2 \tag{26}$$

has the same value for all sets of corresponding parts throughout the whole net, ρ_w being the density of water.

(c) Then the length, L, of the bar of a mesh should be determined so that this ratio:

$$\frac{D'}{D} = \frac{L'}{L} = M \tag{27}$$

has an arbitrary constant value for sets of corresponding parts. Notice that this value can be chosen independently of the reduction ratio Λ.

(d) Assemble the webbings to the frame line or seam the webbings to each other with the same ratio of take-up for corresponding parts of both nets. This means:

$$\varphi = \varphi' \tag{28}$$

when both nets assume similar shapes.

(e) For the model thus made up, the ratio of velocity, V, between model and full-scale net is given by:

$$\frac{v'}{v} = V. \tag{29}$$

(f) The ratio, T, of tension in the webbing (the force acting per unit length of webbing) and the ratio of force, F, at any fixed point in the net are given, respectively, by:

$$\frac{T'}{T} = \Lambda V^2, \tag{30}$$

$$\frac{F'}{F} = \Lambda^2 V^2. \tag{31}$$

The force that acts uniformly upon the edge of the netting (i.e., the buoyancy of floats per unit length of corkline, or apparent weight of sinkers per unit length of leadline) should be determined by means of equation (30). Equation (31) describes the relation of forces that act on a definite point in the net, such as the towing force of a trawl net, or the holding power of the mooring rope in a fixed net.

(g) Sometimes the net changes its form in operation, as in the case of the purse seine. Then the distance which a definite point in the net must travel to complete a definite stage of process is proportional to the net's size λ, and the time, t, required to complete a definite process will be proportional to its linear size, and inversely proportional to its velocity, v. Thus we have:

$$\frac{t'}{t} = \frac{\Lambda}{V}. \tag{32}$$

6. MODEL LAW FOR ROPES IN FISHING NETS (Kawakami 1959)

Ropes of various sizes are indispensable in building fishing nets. There are two kinds of ropes, viz., those whose length must be proportional to the size of the net itself (e.g., the framing lines) and, on the other hand, those whose length can be varied irrespective of the size of the main body of the net, as is the case of towing warp of a drag-net.

Suppose there are two ropes; one for the model, the other for the full-scale net. Then consider the conditions to be fulfilled to make them both similar in shape. As with netting, there are three forces that act on part of a rope in a current:

(a) the hydrodynamic force that arises from the flow,
(b) the weight of the rope in water, and
(c) the tension in the rope at the segment.

In order to get a geometrical and mechanical similarity for both ropes, it is necessary that the ratio between these forces be the same at each similar point on both ropes. Experiments have shown that the force acting on a rope in a uniform current of velocity, v, is practically normal to the rope, and that its magnitude varies proportionately with the square of sine of the angle, θ, between the rope and the current, and also with the square of the current velocity, v. Therefore, the hydrodynamic resistance, r_r, acting per unit length of the rope due to the current is given by the form:

$$r_r = r_{ro} \sin^2\theta\, D_r v^2\,, \tag{33}$$

where r_{ro} is a constant and D_r is the diameter of the rope.

The apparent weight of rope of unit length in water is simply given by:

$$w_r = \pi\left(\frac{D_r}{2}\right)^2 (\rho_r - \rho_w) \tag{34}$$

where ρ_r denotes the density of the rope.

On the other hand, the tension, F_r, in a rope must be proportional to the forces that act upon the point at which the rope is attached to the net:

$$F_r \propto F \tag{35}$$

In order to maintain mechanical similarity, these three forces must be in the same ratio with one another for two ropes, i.e., those of the full-scale net and its model. Hence, denoting the length of the rope by l, from the equation (31), we have:

$$\frac{l'r_r'}{lr_r} = \frac{l'w_r'}{lw_r} = \frac{F_r'}{F_r} = \frac{F'}{F} = \lambda^2 V^2 \tag{36}$$

In making the model, the mean density of a rope can be adjusted by inserting short strips of rope of different materials at regular intervals in proportion of $(a : 1)$. For a small model, this can easily be done by using modern chemical adhesives. Let ρ_r^* and D_r^* be the density and the diameter, respectively, of the inserted material, which may even be a metal filament. Then, if the two ropes maintain a geometrical similarity, i.e., $\theta' = \theta$, the equation given above becomes:

$$\frac{l'[(1-a)D_r' + aD_r^*]v'^2}{lD_r v^2} \tag{37}$$

$$= \frac{l'[(1-a)D_r'^2(\rho_r' - \rho_w) + aD_r^{*2}(\rho_r^* - \rho_w)]}{lD_r^2(\rho_r - \rho_w)}$$

$$= \frac{F_r'}{F_r} = \lambda^2 V^2. \tag{38}$$

This is the most general expression of the model law for ropes. Several cases will be deduced from this:

(a) The first is:

When the rope is used as a main part of the net, the reduction ratio should be equal to that of the main body of the net, i.e.:

$$a \neq 0, \quad \frac{l'}{l} \equiv \lambda_r = \lambda,$$

the equation (36) becomes:

$$\left.\begin{aligned} \frac{(1-a)D_r' + aD_r^*}{D_r} &= \lambda, \\ \frac{(1-a)D_r'^2(\rho_r' - \rho_w) + aD_r^{*2}(\rho_r^* - \rho_w)}{D_r^2(\rho_r - \rho_w)} &= \lambda V^2. \end{aligned}\right\} \tag{39}$$

The density and the size of the rope should be chosen so as to satisfy simultaneously the above two relations.

(b) The second case is:

Usually where

$$a = 0, \text{ and } \frac{l'}{l} = \lambda,$$

the relations are simplified to:

$$\left.\begin{aligned} \frac{D_r'}{D_r} &= \lambda, \\ \frac{\rho_r' - \rho_w}{\rho_r - \rho_w} &= \frac{V^2}{\lambda}. \end{aligned}\right\} \tag{40}$$

(c) The third case is:

If

$$a = 0, \text{ and } \frac{l'}{l} \equiv \lambda_r \neq \lambda,$$

we have:

$$\left.\begin{aligned} \frac{D_r'}{D_r} &= \frac{\lambda^2}{\lambda_r}, \\ \frac{\rho_r' - \rho_w}{\rho_r - \rho_w} &= \frac{V^2\lambda_r}{\lambda^2}. \end{aligned}\right\} \tag{41}$$

This is the case where the rope length is independent of the size of the main body of the net, as in the case of the towing warp of a trawlnet.

In usual cases, since the ropes in a fishing net have less influence on its mechanical properties than its webbing, rigorous observations for this law will be needless, except in the case of the towing warps of trawlnets.

If a net is worked in a relatively weak current, e.g., with a fixed net set in a cove, the resistance of the rope (due to the current) is negligible in comparison with its apparent weight in water. We can then ignore the expression (37); then for case (b) mentioned above, the values of D_r and ρ_r can be chosen so as to satisfy only the next relation:

$$\frac{D_r'^2}{D_r^2}\,\frac{\rho_r' - \rho_w}{\rho_r - \rho_w} = \lambda V^2. \tag{42}$$

If a net is worked in a relatively strong current, as in the case of high speed trawling, the weight of the rope is negligible compared with its resistance; then the relations (38) are simplified to:

$$\frac{D_r'}{D_r} = \lambda. \tag{43}$$

7. MODEL LAW FOR FLOATS AND SINKERS

Floats and sinkers are used to impart a constant buoyancy or gravity to a point or along an edge of

fishing nets. Therefore, these two forces, together with the force or tension in the webbing, must keep the same ratio between similar locations in the full scale and its model.

Denote by n the number of these accessories attached per unit length of the webbing and put:

$$\frac{n'}{n} \equiv N. \tag{44}$$

Then if D_a and ρ_a are the size and density, and if the shape of these accessories is geometrically similar, the buoyancy or gravity per unit length, w_a, is represented by:

$$w_a = k_w D_a^3(\rho_a - \rho_w)n, \tag{45}$$

and resistance r_a by:

$$r_a = k_r D_a^2 v^2 n, \tag{46}$$

where k_w and k_r are constants depending upon the form of the accessories.

Therefore the necessary condition to be fulfilled is:

$$\frac{D_a'^3(\rho_a' - \rho_w)n'}{D_a^3(\rho_a - \rho_w)n} = \frac{D_a'^2 v'^2 n'}{D_a^2 v^2 n} = \frac{T'}{T} = \Lambda V^2. \tag{47}$$

From these relations it follows that:

$$\left.\begin{aligned} \frac{\rho_a' - \rho_w}{\rho_a - \rho_w} &= V^2 \Lambda \Big/ \frac{N}{\Lambda}, \\ \frac{D_a'}{D_a} &= \sqrt{\frac{\Lambda}{N}}. \end{aligned}\right\} \tag{48}$$

Strictly speaking, floats or sinkers of the model should satisfy these two relations simultaneously.

It occurs frequently that the model accessories cannot be made up in strict sense with the real materials due to the extraordinary denseness of these materials. This difficulty may be overcome by neglecting the hydrodynamic resistance acting on the accessories in comparison with their buoyancy or gravity. This may be allowable if the current velocity is not too high. Thus the second term of equation (47) is ignored and we have:

$$\frac{D_a'^3(\rho_a' - \rho_w)}{D_a^3(\rho_a - \rho_w)} = \frac{V^2 \Lambda}{N} \tag{49}$$

in place of the relations in (48).

When these accessories are attached to a fixed point in a gear, as is the case with the king buoy of a pound net or the tom weight of a purse seine, similar considerations, from equation (31), give:

$$\frac{D_a'^3(\rho_a' - \rho_w)}{D_a^3(\rho_a - \rho_w)} = \frac{D_a'^2 v'^2}{D_a^2 v^2} = \frac{F'}{F} = \Lambda^2 V^2, \tag{50}$$

from which it follows that:

$$\left.\begin{aligned} \frac{D_a'}{D_a} &= \Lambda, \\ \frac{\rho_a' - \rho_w}{\rho_a - \rho_w} &= \frac{V^2}{\Lambda}. \end{aligned}\right\} \tag{51}$$

When the accessory causes a hydrodynamic force, as in the case of otter boards in a trawlnet, its size and material should satisfy these relationships simultaneously. If, however, its apparent weight in water is negligible when compared with its hydrodynamic resistance, it may be sufficient if only the first relationship in expression (51) is fulfilled.

When the net is fixed to the sea bottom by sand bags, as in the case of a fixed trap net, the weight, W, of the bag in water should be chosen so as to satisfy the relation:

$$\frac{W'}{W}\frac{k'}{k} = \Lambda^2 V^2, \tag{52}$$

where k is the holding coefficient of the bag to the sea bottom.

8. THE CASE IN WHICH THE RATIO OF SCALE REDUCTION MODEL IS DIFFERENT IN THE HORIZONTAL AND VERTICAL DIRECTIONS (Kawakami).

It is sometimes requested that a model net should be made up in such a manner that the horizontal and vertical reduction ratios are different from each other. For instance, imagine a long, narrow gillnet several hundred metres long, several metres deep. In this case, if we intend to construct an ordinary geometrically similar model, the depth of the model would be extremely small. In this section, we shall consider the case in which the reduction ratio in horizontal direction:

$$\frac{\lambda'_h}{\lambda_h} = \Lambda_h$$

differs from that in the vertical direction:

$$\frac{\lambda'_v}{\lambda_v} = \Lambda_v.$$

The gravity and buoyancy do not act in the horizontal direction, but they do act in the vertical direction. Therefore, corresponding with equation (20), we have next two relations:

$$\frac{\lambda_h' \lambda_v'[(D'/L') + h(D'/L')^2]v'^2}{\lambda_h \lambda_v[(D/L) + h(D/L)^2]v^2} = \frac{\lambda'_v T_h'}{\lambda_v T_h} = \frac{F_h'}{F_h}, \tag{53}$$

$$\frac{\lambda'_h \lambda'_v[(D'/L') + a(D'/L')^2]D'(\rho' - \rho_w)}{\lambda_h \lambda_v[(D/L) + a(D/L)^2]D(\rho - \rho_w)}$$

$$= \frac{\lambda'_h \lambda'_v[(D'/L') + h(D'/L')]v'^2}{\lambda_h \lambda_v[(D/L) + h(D/L)]^2 v^2} = \frac{\lambda_h' T_v'}{\lambda_h T_v} = \frac{F_v'}{F_v}, \quad (54)$$

where subscripts h and v denote horizontal and vertical. Similar treatment as in Section 5 would result as follows:

If we chose the netting of the model so as to satisfy the relation:

$$\frac{D}{L} = \frac{D'}{L'}, \quad (55)$$

the above relations will be simplified to

$$\Lambda_h \Lambda_v \frac{v'^2}{v^2} = \Lambda_v \frac{T_h'}{T_h} = \frac{F_h'}{F_h},$$

$$\Lambda_h \Lambda_v \frac{D'(\rho' - \rho_w)}{D(\rho - \rho_w)} = \Lambda_h \Lambda_v \frac{v'^2}{v^2} = \Lambda_h \frac{T_v'}{T_v} = \frac{F_v'}{F_v}. \quad (56)$$

Then putting:

$$\frac{D'(\rho' - \rho_w)}{D(\rho - \rho_w)} \equiv V^2, \quad (57)$$

we have:

$$(58)$$

$$\frac{T_v'}{T_v} = \Lambda_v V^2, \quad (59)$$

$$\frac{T_h'}{T_h} = \Lambda_h V^2, \quad (60)$$

$$\frac{F_v'}{F_v} = \frac{F_h'}{F_h} = \Lambda_h \Lambda_v V^2. \quad (61)$$

9. THE CASE IN WHICH ACCELERATION DUE TO WAVE MOTION CANNOT BE NEGLECTED (Kawakami, 1961)

When gear which operates at or near the surface, such as the driftnet, is subjected to the effect of wave motion, and when the mass of the accessory is large enough, the force due to acceleration cannot be ignored. Here some further considerations will be presented.

According to the theory of "surface waves", the period, t_p, of the wave motion is given as a function of the wave length, l, as follows:—

$$t_p = \sqrt{\frac{2\pi l}{g}}, \quad (62)$$

where g denotes the gravity acceleration. If the height of the wave at the surface be denoted by $2r_o$ the radius of orbit of the water motion at a depth z is given by:

$$r = r_o \exp(-2\pi z/l). \quad (63)$$

Hence at geometrically similar points, $z'/z = l'/l$, we have:

$$\frac{r'}{r} = \frac{r_o'}{r_o}. \quad (64)$$

Therefore, if the reduction rate, Λ, of the model is equal to that of the wave length and if both waves are geometrically similar,

$$\frac{l'}{l} = \frac{r'}{r} = \frac{r_o'}{r_o} = \Lambda. \quad (65)$$

This means that at corresponding positions of both nets the reduction rate of the orbit of wave motion is equal to that of the model.

The velocity, v_w, of the water motion at a corresponding position is given by:

$$\frac{v_w'}{v_w} = \frac{r'/t_p'}{r/t_p} = \frac{\lambda'}{\lambda}\sqrt{\frac{l}{l'}} = \sqrt{\Lambda}. \quad (66)$$

Remembering equation (29), this gives:

$$V^2 = \Lambda.$$

This is the conclusion drawn from the fact that the velocities of both the net and the water are determined by the wave length.

The acceleration, a, of the sinker under consideration is proportional to r/t_p^2, then we have:

$$\frac{a'}{a} = \frac{r'/t_p'^2}{r/t_p^2} = \frac{r'}{r}\frac{l}{l'} = 1, \quad (67)$$

i.e., the magnitude of acceleration of both nets is equal, irrespective of their sizes.

Now we consider a leadline to which n sinkers per unit length are attached; and let the mass of the sinker and its acceleration be so large that the hydrodynamic resistance can be neglected in comparison with the apparent weight and the inertia. Let ρ_s be the density of the material and D_s be its size. Then the apparent weight per unit length of the leadline will be proportional to $nD_s^3(\rho_s - \rho_w)$.

In order to accelerate a solid body in a fluid, it is not only necessary to exert a force equal to the product of the mass of the body and its acceleration, but an additional force to accelerate the mass of the fluid substance set in motion by it. This additional force for various bodies depends on its shape and on the direction of motion, and is represented by supposing that the mass of the body is increased by a certain amount proportional to the product of the density of the fluid and the volume of the body. Therefore, this apparent inertia force per unit length of leadline will be represented by nD^3,

$(\rho_s+p\rho_w)a$, where p is a constant depending on the shape of the sinker and on the direction of motion.

Therefore the necessary condition to be fulfilled is written in the same manner as expressed by equation (47):

$$\frac{D_s'^3(\rho_s' - \rho_w)n'}{D_s^3(\rho_s - \rho_w)n} = \frac{D_s'^3(\rho_s' + p\rho_w)a'n'}{D_s^3(\rho_s + p\rho_w)an} = \frac{T'}{T} = \Lambda V^2. \tag{68}$$

Hence if we could choose the material of the sinker so as to satisfy the relation:

$$\frac{\rho_s' - \rho_w}{\rho_s - \rho_w} = \frac{\rho_s' + p\rho_w}{\rho_s + p\rho_w} = \frac{\rho_s'}{\rho_s} = \frac{\rho_w}{\rho_w} = 1, \tag{69}$$

taking the relations (66) and (67) into consideration and writing $n'/n \equiv N$ as before, it follows that:

$$\frac{D_s'^3}{D_s^3} = \frac{\Lambda V^2}{N} = \frac{\Lambda^2}{N}. \tag{70}$$

Then if the total number of sinkers is equal in both nets, i.e., $N\Lambda=1$, we have:

$$\frac{D_s'}{D_s} = \Lambda. \tag{71}$$

These results lead to the conclusion that, if the model is to be built of the same material as the full-scale gear, the reduction of size must be the same throughout every part of the gear.

10. LAW OF ENLARGEMENT OF FISHING NET (Kawakami, 1961)

In the preceding sections we have not been concerned with the tension acting in the bars of mesh. This tension becomes highly significant in connection with the tensile strength of netting twine, at times when we wish to enlarge a given full-scale gear, without changing its design, to a proper size for the special case which confronts us.

It seems to leave no margin for adjusting the breaking strength of the twine, except for choosing the material, in the preceding theory of mechanical similarity. Here we must make some compromise. For this purpose, the writer has made an assumption that the resistance and apparent weight of a knot are much smaller than those of two bars. This may be allowable for ordinary gear where the value of (D/L) is less than 1/10. Under this assumption, we can neglect the term $(D/L)^2$ as compared with the term (D/L) and equations (7) and (15) will be simplified, respectively, to:

$$w = f(\varphi)\left(\frac{D}{L}\right)D(\rho - \rho_n), \tag{72}$$

$$r = f(\varphi, \theta)\left(\frac{D}{L}\right)v^2. \tag{73}$$

Next, consider the tension, τ, in a netting twine of a gear in action. Let n be the number of meshes in unit length. Then n is inversely proportional to $(L \sin \varphi)$, or strictly, as shown in Fig. 4:

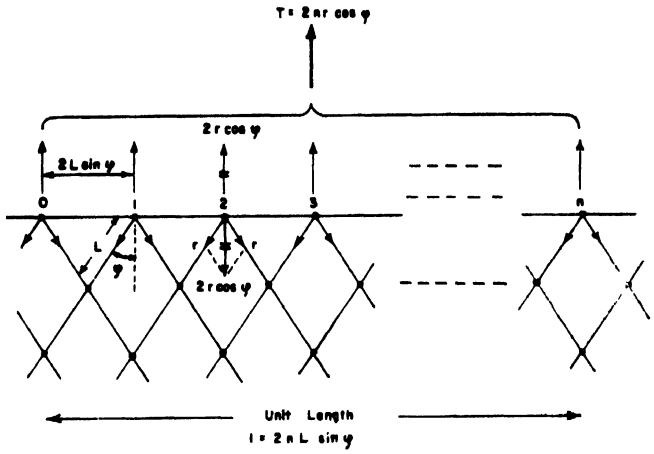

Fig. 4. Tension in the netting end in the twine.

$$n = \frac{1}{2L \sin \varphi}, \tag{74}$$

and the tension in a bar is given by:

$$\tau = \frac{T}{2n \cos \varphi} = TL \tan \varphi. \tag{75}$$

On the other hand, the tension which a twine can bear, or breaking strength, is clearly the product of the tensile strength, σ, of the material and its cross-sectional area (proportional to D^2), and τ must not exceed this breaking strength, i.e.:

$$\pi\left(\frac{D}{2}\right)^2\sigma > \tau = TL \tan \varphi. \tag{76}$$

Thus for the critical condition we have:

$$T = q(\varphi)\frac{D^2}{L}\sigma, \tag{77}$$

where the coefficient q is determined by the openness of the mesh or angle φ. Then equation (20) may be transformed into:

$$\frac{\lambda'^2(D'/L')D'(\rho' - \rho_w)}{\lambda^2(D/L)D(\rho - \rho_w)} = \frac{\lambda'^2(D'/L')v^2}{\lambda^2(D/L)v^2} = \frac{\lambda'T'}{\lambda T} = \frac{\lambda'(D'^2/L')\sigma'}{\lambda(D^2/L)\sigma} = \frac{F'}{F}. \tag{78}$$

This is analogous as treated in Section 5, where we had three ratios which we could determine arbitrarily according to the circumstances. But in this case one more degree

of freedom is increased due to the relaxation of the restriction on the forces acting upon the knot. Hence if we choose four arbitrary ratios as follows:

$$\frac{\lambda'}{\lambda} \equiv \Lambda, \quad \frac{L'}{L} \equiv M, \quad \frac{\rho' - \rho_w}{\rho - \rho_w} \equiv P, \quad \frac{v'}{v} \equiv V,$$

the equation (78) is written:

$$\Lambda^2\left(\frac{D'}{D}\right)^2\frac{P}{M} = \Lambda^2\left(\frac{D'}{D}\right)\frac{V^2}{M} = \Lambda\frac{T'}{T} = \left(\frac{D'}{D}\right)^2\frac{\Lambda\sigma'}{M\sigma} - \frac{F'}{F}. \tag{79}$$

From these relations it follows that:

$$\frac{\sigma'}{\sigma} = \Lambda P, \tag{80}$$

$$\frac{D'}{D} = \frac{V^2}{P}, \tag{81}$$

$$\frac{T'}{T} = \frac{\Lambda V^4}{PM}, \tag{82}$$

$$\frac{F'}{F} = \frac{\Lambda^2 V^4}{PM}. \tag{83}$$

This is the relation which determines the tensile strength and diameter of the twine, amount of sinkers or floats per unit length of webbing, and the force which should be applied to the manipulating or mooring rope.

There is, however, another point of view. The strength of webbing should not only be determined by its tolerance against the tension in its underwater operation, but also by its endurance against the tension exerted by the brailing of catch on to the vessel. Let us focus our attention on this point.

We assume at first that the amount of catch is proportional to the volume of the net, i.e., the weight which the webbing must sustain is proportional to the cube of the linear size of the net. This tension due to the weight of catch is quite different in its nature from that due to the underwater operation, but the equation (77) is valid, irrespective of the origin of the tension. Hence, if we denote the diameter of the twine determined from this point of view by D^*, we have:

$$\frac{\lambda'^3}{\lambda^3} = \frac{\lambda' T'}{\lambda T} = \frac{\lambda'(D^{*2}/L')\sigma'}{\lambda(D^2/L)\sigma} \tag{84}$$

or

$$\frac{D^*}{D} = \sqrt{\frac{\Lambda M}{P}}. \tag{85}$$

The value of D^* obtained by this way must be compared with that of D' obtained previously. If the value of D^* is noticeably larger than that of D', the material of the twine should be replaced by a stronger material; otherwise the use of some rib-lines, for reinforcement, is advisable.

Here, in order to avoid the apparent contradiction in the diameters of the twine obtained by the working condition and by the brailing operation, equate equation (81) with equation (85) and take expression (80) into account. We get:

$$V^4 = \Lambda MP \tag{86}$$

or

$$\frac{\sigma'}{\sigma} = \frac{V^4}{M}. \tag{87}$$

The problem with which we shall be confronted will depend on whether we can find the material that satisfies this condition.

It may be worthwhile to notice that fishing nets can their mechanical behaviour. Every fishing net takes its proper form during its operation by being subjected to the influences of gravity and current, as explained before. However, there is one type of net which takes its proper form mainly by the action of gravity and is this is the case with the bag of a pound net. Another type, which takes its ideal form from the current and is undesirably deformed by the action of gravity is the case with the towed net. We tentatively call the former the "gravity type", and the latter the "resistance type".

Now, for instance, let us consider the resistance type in which the tension in the webbing will be caused mainly by the resistance due to the current, and the form of the net is hardly influenced by the gravity. In this case, the first term of equation (78) is dropped, and one more degree of freedom may appear. Thus we are allowed to choose the ratio of tensile strength as the factor which can be determined freely, i.e., put:

$$\frac{\sigma'}{\sigma} \equiv S, \tag{88}$$

the analogous treatment as before gives:

$$\frac{D'}{D} = \frac{V^2\Lambda}{S}, \tag{89}$$

$$\frac{T'}{T} = \frac{\Lambda^2 V^4}{MS}, \tag{90}$$

$$\frac{F'}{F} = \frac{\Lambda^3 V^4}{MS}, \tag{91}$$

and as to D^*, we have:

$$\frac{D^*}{D} = \Lambda\sqrt{\frac{M}{S}}. \tag{92}$$

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The Development of a Midwater Trawl

Abstract

The paper outlines the objectives, organisation and methods of the Norwegian Government-sponsored APE group (Working Group for the Development of the One-boat Midwater Trawl). It is pointed out that ideas arising from technical research will often appear upsetting and that their adoption requires not only confidence in, but an understanding of, science and scientific method. A strong plea is made for unfettered international co-operation in research. A step in this direction was the establishment of the International Group for Pelagic Fishing Methods and Gear (IF), in which six countries now co-operate in a programme comprising standardisation of descriptive methods and technological gear research.

Le développement d'un chalut pélagique

Résumé

La communication décrit les objectifs, l'organisation et les méthodes utilisées par l'APE (Groupe de Travail pour le Développement du chalut pélagique à un bateau), groupe financé par le Gouvernement Norvégien. Les auteurs de cet article attirent l'attention sur le fait que certaines idées provenant de la recherche technique paraissent souvent incroyables et que leur adoption requiert non seulement une certaine confiance mais aussi une compréhension de la science et de ses méthodes et plaident en faveur d'une coopération internationale libre dans la recherche. L'établissement d'un Groupe International pour les méthodes et engins de pêche pélagique (I.F.) constitute un pas dans cette voie et six pays coopèrent actuellement à un programme comprenant la standardisation des méthodes descriptives et la recherche technologique sur les engins.

El perfeccionamiento del barco de arrastre flotante

Extracto

Da a conocer la ponencia las finalidades, organización y métodos del grupo APE (Comité para el Perfeccionamiento de un Arte flotante remolcado por una Embarcación) patrocinado por el Gobierno noruego. Se hace observar que los resultados obtenidos por la investigación técnica con frecuencia parecen ser desconcertantes y su aplicación no sólo necesita confianza sino también comprensión de la ciencia y los métodos científicos. Se aboga vigorosamente por la cooperación internacional sin trabas en a investigación. Un paso en esta dirección fue la creación de un grupo internacional para métodos y artes de pesca pelágica (IF) en el que 6 países cooperan en un programa que comprende la normalización de métodos descriptivos y tecnología de la investigación de artes.

by

P. Dale

S. Moller

Norwegian Group. Special working group for one-boat midwater trawl

FOR detailed investigation of fishing gear problems, the Norwegian Government sponsored the formation of a special study group, the working group for the development of a one-boat midwater trawl (APE). The work thereby initiated has been comprehensive and seems likely now to be of a permanent character with far more facets than can be covered in this report.

It is, therefore, necessary at this stage to select those angles of special interest, namely the tests that have so far been conducted in relation to midwater trawling and the development of testing gear.

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It is to be noticed that the density of the material disappears in these relations. This is natural because the action of gravity has been ignored.

11. CONCLUSION

Our present fishing gear is the result of trial-and-error experience over centuries. Fishermen long ago discovered that the simple device is not always the successful one. While respecting these traditions, we must make continuing efforts to improve obvious faults in present gear.

Our modern advantage lies in great and continuing improvements in net material, such as the use of synthetic fibres. Meanwhile, the fundamentals of how to catch fish remain unchanged and we may assume that fish behaviour has also followed constant principles over the centuries. These simple facts mean that our potential to harvest the sea has greatly expanded.

The sea remains largely unknown and its changing faces must remind us that no single method or gear will be the best for all circumstances. Thus the thoughts expressed in this paper do not comprise a body of strict rules. Rather, these laws must be applied to circumstances as they arise.

Despite the changeability of the factors with which we must work, we have no doubt that there must be a general rule for gear design and operation. The challenge is to continue our research toward these general principles. As bigger boats fish more and more distant grounds with larger-scale gear, the challenge will require the net designer to devise mechanical solutions for many new problems.

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The basic research programme is overwhelming and far too wide to be done by one party in a reasonable time. It is a task for international co-operation where all interested nations should contribute without national restrictions. Certain developments along those lines have some promising significance.

The ideas arising from technical research seem too revolutionary and upsetting to many and the adoption of them certainly needs a good deal of confidence in, and understanding of, science and scientific methods. When trying to analyse the problems there is, however, no other safe way to go. Reviewing the time and money spent hitherto on many projects within the pelagic fishery in relation to the results achieved, there is no doubt that, in the long run, the rational approach is the economical way also.

The first step in this direction has already been taken by the establishment of the IF group (International Group for Pelagic Fishing Methods and Gear) wherein six nations share the results from research work done by each in the field of midwater trawling. This group thought these themes were suitable for wide co-operation, namely :

(a) *Standardisation :* Methods and scaling of drawings, terms and definitions, testing methods, test procedure and testing conditions, terminology and specifications of materials.

(b) *Technologic Gear Research:* Hydrodynamics, patterns of fish behaviour, instrumentation, test, installations.

The objective is to simplify comparison of one design with another, to make drawings understandable to anybody, to show characteristics of constructions in a synonymous way; to standardise terminology; to avoid the numerous codes used for specifying materials; to avoid cumbersome and often misleading recalculations; to ease the repair of gear; to realise an effective spare-part service, etc.

There have been numerous objections to this way of tackling the problems, mainly originating in the view that the programme is too big and all-embracing for a restricted tool like a midwater trawl. The APE group is, however, of the opinion that:

(a) This type of fishing gear is one with a great future for many fishing purposes.

(b) It might very well form the basis for new fisheries.

(c) This method of solving the problems has value not only for this specific class of gear but will help the understanding and construction of any gear type, thus also providing possibilities for the improvement of other existing ones.

Viewed from this angle the chosen procedure may not seem so overwhelming but rather the only reasonable one.

The APE group does not think it possible to arrive at formulae covering all phenomena connected with fishing gear or otherwise establish theoretical control that can give an answer to any question that may arise. However, it is thought that a combination of formulae, models and full-scale tests with suitable equipment, test installations and test procedures framed by a pattern made up from empirical data will give answers to most questions of importance. This should also help to further the general understanding of the underwater behaviour of gear in relation to fish, and will strengthen the foundation for further development.

An example of the work so far done is available in a report on model tests made with three bottom trawl boards, by H. A. A. Walderhaug and A. Akre. We quote extensively from that report which was published in the Norwegian Fishing and Maritime News, No. 1, 1963, thus :

In this report are described some results of otterboard hydrodynamical tests carried out at the Norwegian Ship Model Experiment Tank.

The otterboards tested are all designed for bottom trawls, and following notation is used :

B 1: Rectangular otterboard of orthodox design (Fig. 1).

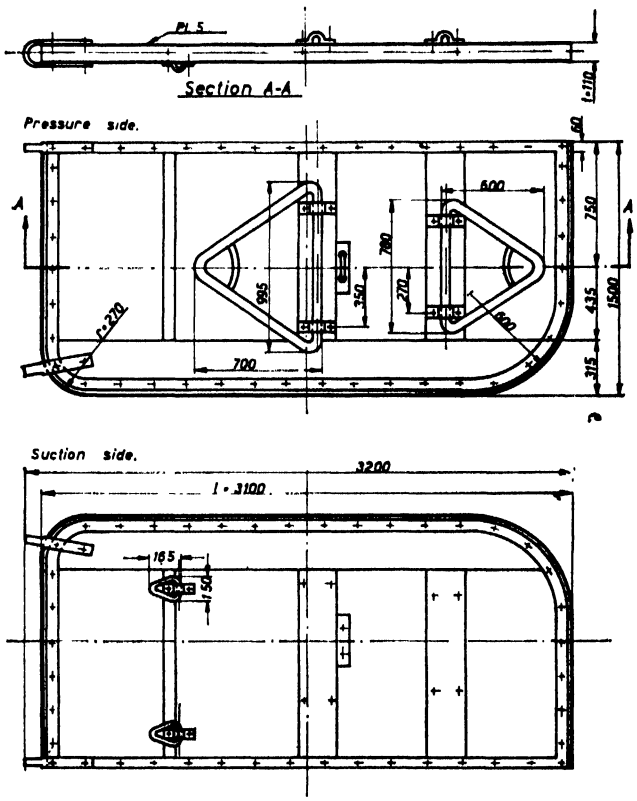


Fig. 1. Otterboard B 1 (Rectangular otterboard). Weight: 1100 kilogram. Area: 456m². t/1: 0·0355. Reynolds' number at towing speed 3·5 knot: 5·5 × 10⁶.

B 2 : Oval otterboard (Matrossow board) with one vertical slot at the centre of the board (Fig. 2).

B 3 : Oval otterboard with 3 slots (Fig. 3).

B 2a: As B 2, but with 2 slots, one at the centre and one at the leading edge (Fig. 4).

B 2b : As B 2, but with a streamlined leading edge, NACA wing section (Fig. 4).

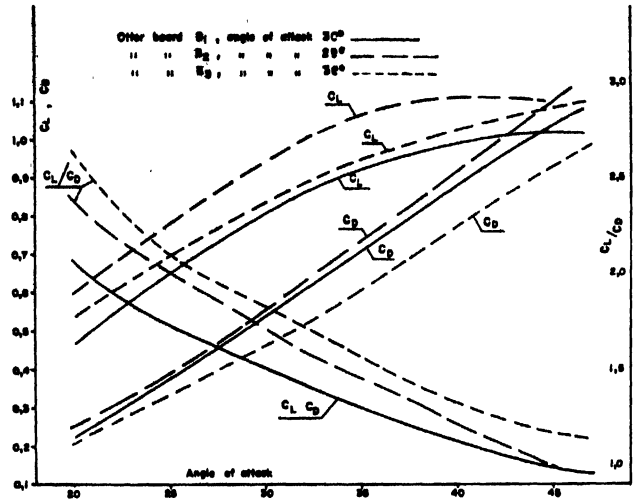


Diagram no. 2. Freestream tests, otterboard B 1, B 2, and B 3. Force coefficient and lift-drag ratio of otterboard as function of angle of attack.

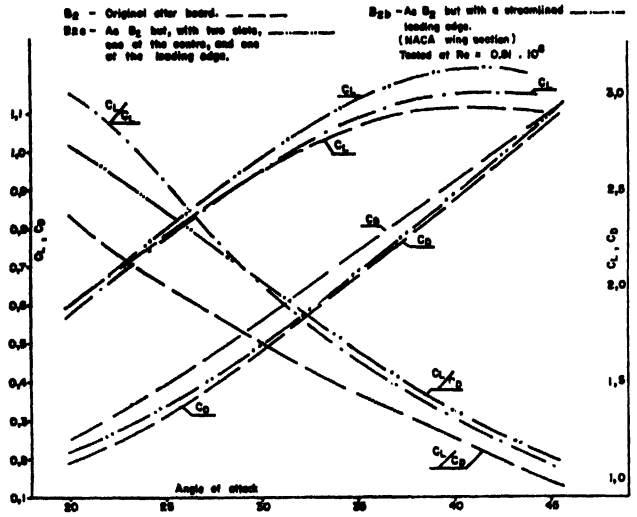


Diagram no. 3. Freestream tests otterboard B 2. Force coefficients and lift-drag ratio of otterboard as function of angle of attack.

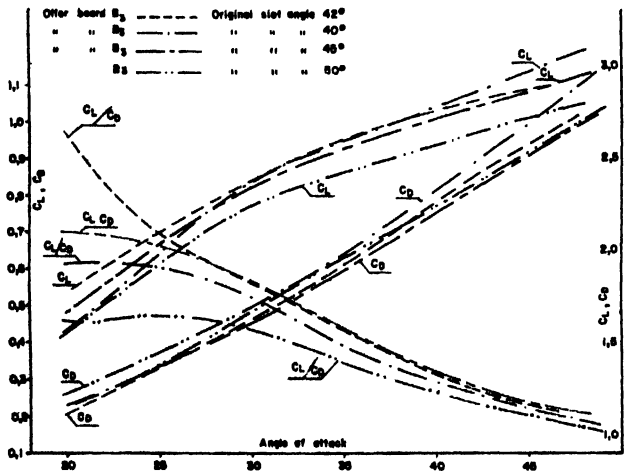


Diagram no. 4. Freestream tests, otterboard B 3. Force coefficients and lift-drag ratio of otterboard as function of angle of attack.

Concerning the modified otterboards, it is shown in Diagram 3 that B 2a as well as B 2b has a 12-13% higher lift-drag ratio than B 2.

In Diagram 4 is shown the effect of varying the slot angle for B 3. The effect is quite marked with a maximum lift-drag ratio at a slot angle between 42° and 45°.

Bottom tests

During these tests the otterboards were towed very close to the bottom (maximum distance about 5 mm) but without actually touching the bottom. Mechanical friction was therefore not involved, and the law of similarity between model and prototype mentioned earlier is still valid.

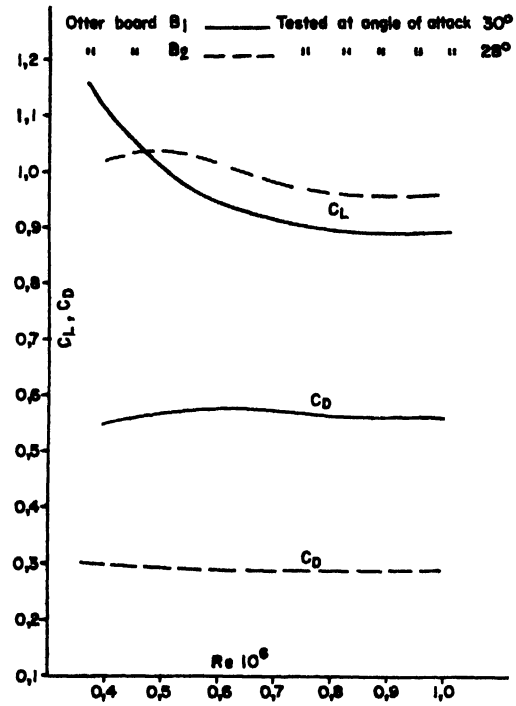


Diagram no. 5. Bottom test, otterboard B 1, B 2. B 2. Force coefficient of otterboard as function of Reynolds' number.

In Diagram 5 is shown the effect of Reynolds' number variations on the force coefficients. It will be observed that the critical Re are higher than those for the open water tests. This effect is more pronounced for B 1 than for B 2, which might have been expected since B 1 has a horizontal bottom line. The critical Re for B 1 and B 2 will be approximately $0{\cdot}8 \times 10^6$.

The effect of variations in angle of attack is shown in the Diagrams 6, 7, 8, 9 and 10. It will be observed that the maximum lift for the three parent otterboards (Diagram 6) will be reached at a smaller angle of attack than during the open water tests. This effect might have been expected since stalling is delayed by 3-dimensional effects.

As for the open water tests the maximum lift-drag ratio will occur at an angle of attack less than 20°, and the rectangular otterboard is still inferior to the other two.

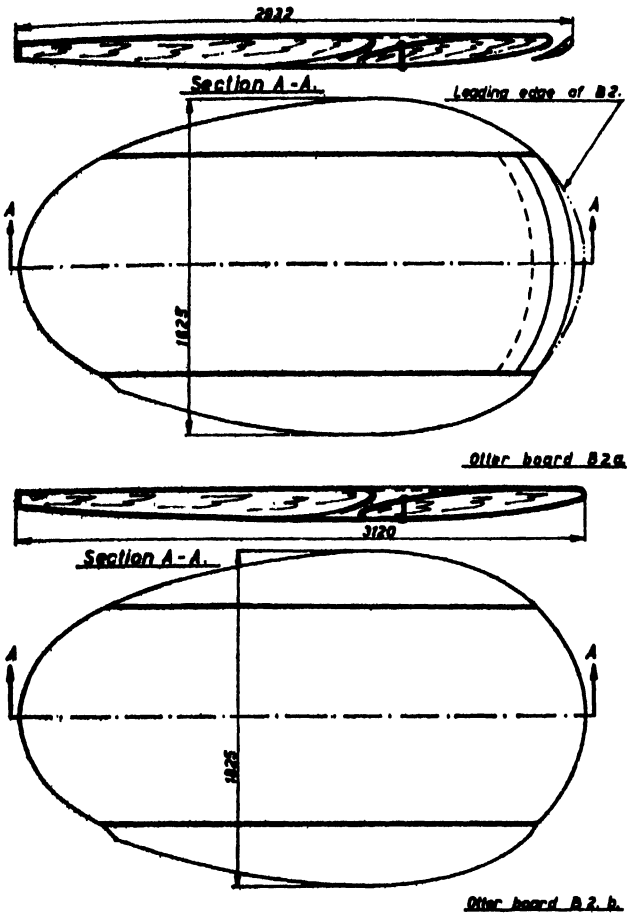


Fig. 4. Otterboard B 2a, B 2b. Modifications of otterboard B 2.

Reynolds' number is defined as

$$\mathrm{Re} = \frac{Vc}{\nu}$$

where

c = length of otterboard (cord)
ν = kinematic viscosity.

Scale effects—Model size

The first problem in model testing is to find a relation between model and prototype as regards forces and moments. The forces involved when an otterboard is towed deeply submerged in water are frictional forces and inertia forces, and the streamlines around the model and prototype are geometrically similar if Reynolds' number is the same for model and prototype. This can not easily be realised in a model tank, but fortunately the force and moment coefficients are practically independent of Reynolds' number variations for Re larger than $0{\cdot}5 \times 10^6$—1×10^6. As model scale for B 1 and B 2 were chosen 1:5, and for B 3, which is a smaller otterboard, were chosen the scale 1:4. With these models the critical Reynolds' number mentioned above is reached in the model tank.

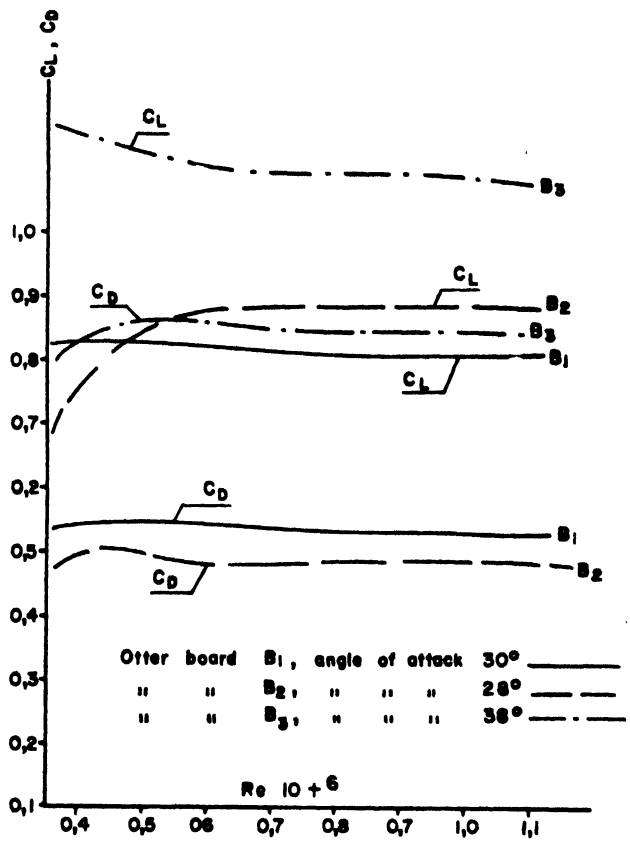


Diagram no. 1. Freestream tests, otterboard B 1 and B 2. Force coefficient as function of Reynolds' number.

Free stream (open water) tests

In Diagram 1 are shown the force coefficients of otterboards B 1 and B 2 as a function of Reynolds' number. B 2 is tested in this series at two angles of attack, i.e. 28° and 38°, and for this board the force coefficients will be approximately independent of Re for Re larger than $0{\cdot}65 \times 10^6$. The critical Re for the rectangular otterboard B 1 is lower, approximately $0{\cdot}5 \times 10^6$. The higher critical speed of B 2 than that of B 1 may be due to the shape of the otterboard as well as the effect of the slot.

Based on this test series and on results of airfoil tests (see f ex the British Shipbuilding Research Association, Reports No. 70 and 142) it is expected that full-scale behaviour of otterboard in open water may be predicted from model test carried out at a Re of at least $0{\cdot}65 \times 10^6$.

The force coefficients and lift-drag ratios as a function of angle of attack is given in Diagrams 2, 3 and 4. Only the angles of attack between 20° and 45° have been considered of practical interest; however, the efficiency or lift-drag ratio of the otterboards will have a maximum at an angle of attack less than 20°.

It may be observed from the curves that otterboard B 3 has the highest L-D ratio, whereas B 2 has the highest lift-coefficient.

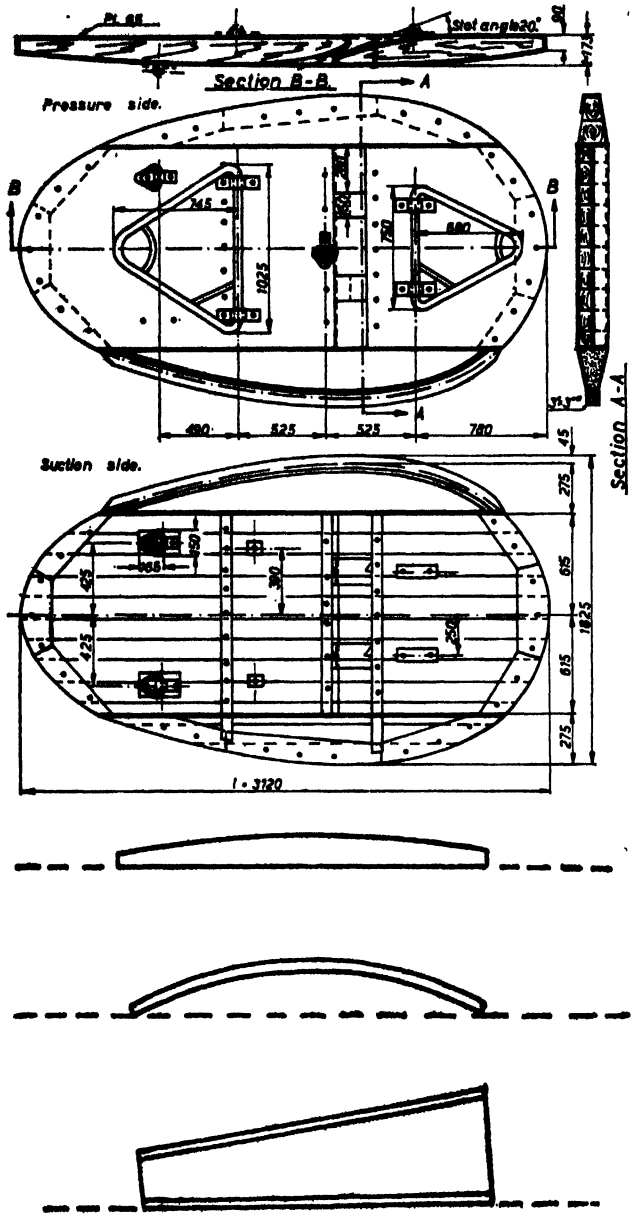


Fig. 2. Otterboard B 2. Oval otterboard with one slot. Weight: 950 kilogram. Area: 4·55 m². t/l: 0·0555. Reynolds' number at towing speed 3·5 knot: 5,56 × 10⁶.

B 2c : As B 2, but without slot.

B 1a and B 2d : As B 1 and Ba respectively, but without fittings such as brackets, strengthening strips and edges, hooks, links for back strops, bolts, pints, etc.

B 3a, b, c : As B3, but with slot angles equal to 40°—45° and 50° respectively.

The slot angle for B 3 is 42°, where the slot angle is defined as the angle between the after slot cord line and the otterboard cord line (Fig. 3).

The following definitions were made in order to relate otterboard model tests to tests with the complete trawl gear:

The tangent plane is defined as the plane tangent to the pressure side of the otterboard. Some examples of tangent planes are shown with dotted lines in the sketch.

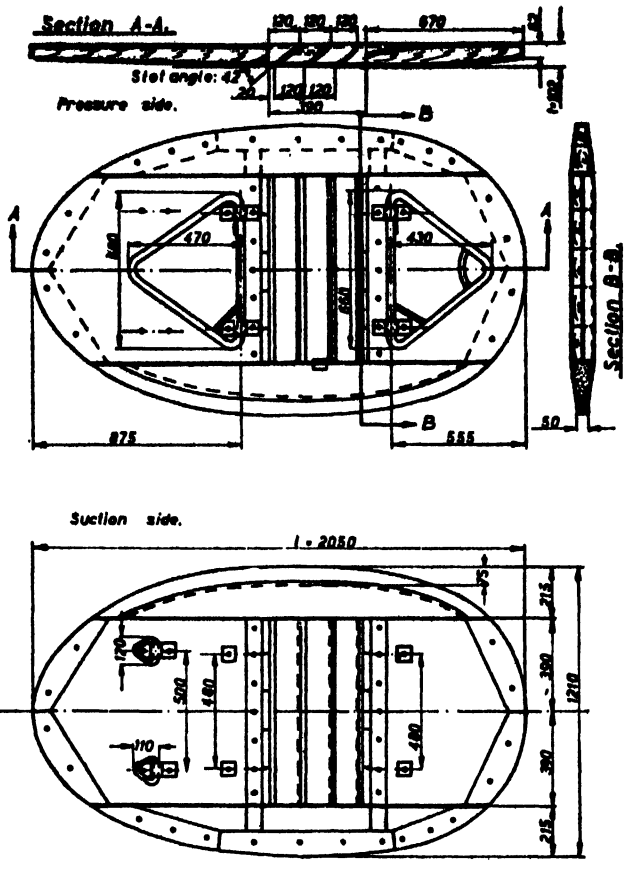


Fig. 3. Otterboard B 3. Oval otterboard with three slots. Weight: 290 kilogram. Area: 2035m². t/l: 0·0498. Reynolds' number at towing speed 3·5 knot 3·6 × 10⁶.

For the otterboards described in this report the tangent planes and pressure sides are synonymous.

The reference plane is defined as a vertical plane parallel to the speed direction (speed vector).

During the tests described the angle of inclination and the angle of tilt were both zero, so that the tangent plane was always vertical.

The angle of attack, a is measured in a plane through the speed vector and perpendicular to the tangent plane.

The following nondimensional coefficients are used:

$$CL = \frac{L}{\frac{1}{2}\varrho AV^2} = \text{lift coefficient}$$

$$C_D = \frac{D}{\frac{1}{2}\varrho AV^2} = \text{drag coefficient}$$

L/D= lift/drag ratio

where L = lift force in the plane of the angle of attack and perpendicular to the speed vector.

During the tests the lift and spread forces are synonymous.

D = drag force in the speed direction

ϱ = mass density

A = projected area of otterboard in the tangent plane

V = velocity.

Streamlining the leading edge of the otterboard will increase the lift-drag ratio about 6% at the stalling point (Diagram 8). Further the stalling angle is increased about 4°.

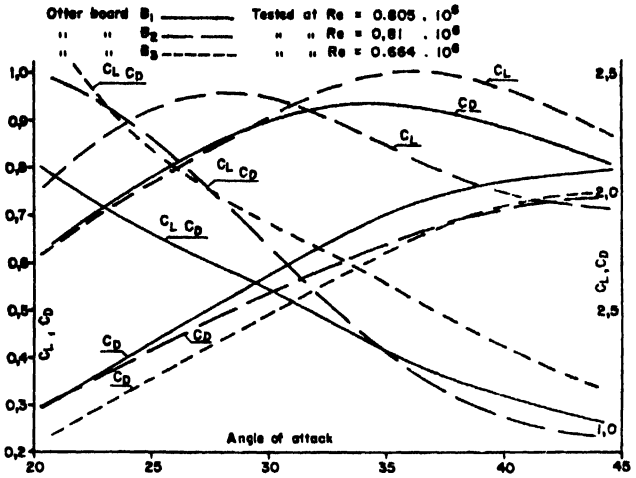


Diagram no. 6. Bottom test, otterboard B 1, B 2 and B 3. Force coefficients and lift-drag ratio of otterboard as function of angle of attack.

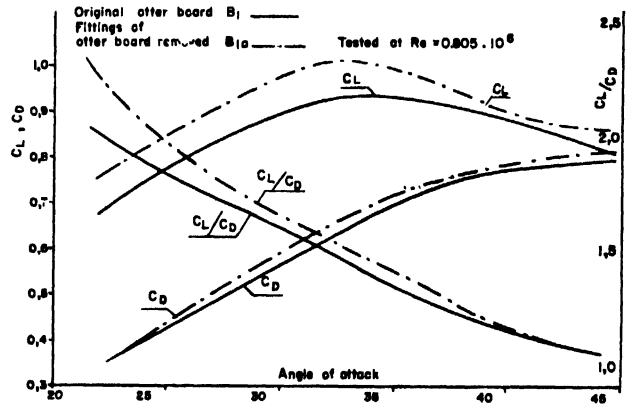


Diagram no. 7. Bottom tests, otterboard B 1. Force coefficient and lift-drag ratio of otterboard as function of angle of attack.

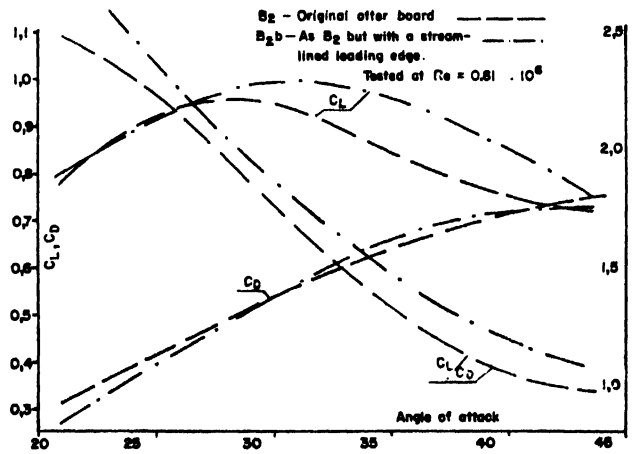


Diagram no. 8. Bottom tests, otterboard B 2. Force coefficient and lift-drag ratio of otterboard as function of angle of attack.

The effect of the slot in B 2 is comparatively small as shown in Diagram 9. At the point of maximum lift, the slot seems to increase the lift-drag ratio about 5%.

Removing the otterboard fittings has a very marked effect on the lift characteristics as shown in Diagrams 7 and 10. The lift is increased by 10%-15% and the lift-drag ratio is increased by 5%-7%. Further the stalling angle is reduced 3° for B 2. The increase in drag may be the net result of a reduced frictional resistance and an increased induced resistance.

Comments on the test results

First consider Diagram 2. It may be observed from these curves, valid in open water, that otterboard B 3 has the highest L-D ratio, whereas B 2 has the highest lift-coefficient. Which is the best otterboard is not obvious. However, we may compare the boards on a basis of constant area or constant lift-coefficient when the speed is regarded as constant. In that case we draw a horizontal line through f ex the lift-coefficient of B 2 at $\alpha = 30°$. Where this line crosses the CL curves of B 3 and B 1 we proceed vertically downwards to the

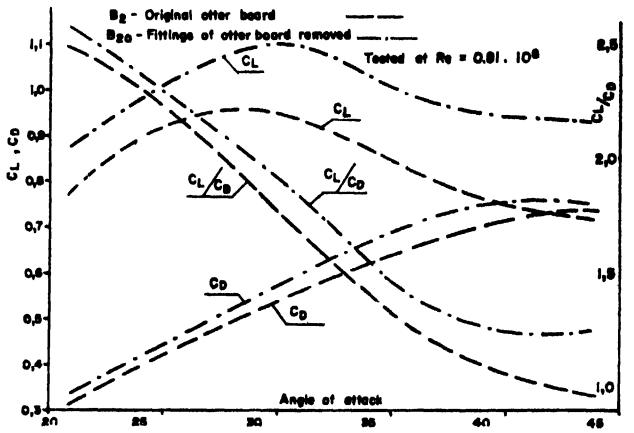


Diagram no. 9. Bottom tests, otterboard B 2. Force coefficient and lift-drag ratio of otterboard as function of angle of attack.

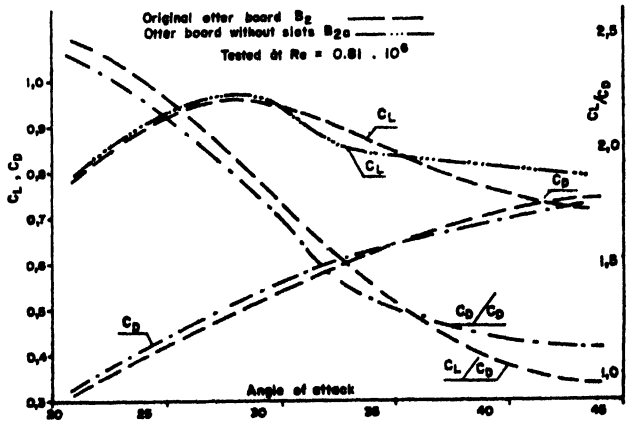


Diagram no. 10. Bottom tests, otterboard B 2. Force coefficient and lift-drag ratio of otterboard as function of angle of attack.

respective L-D ratio curves. We then find that B 2 is approximately 9% better than B 3 and approximately 40% better than B 1. The corresponding angle of attack of B 3 and B 1 is approximately 35° and 36·5° respectively.

We may also compare B 2 and B 3 on a basis of constant angle of attack, f ex 30°. If the two boards shall have the same lift at this angle of attack, we find by considering the definition of lift-coefficients, that the areas of the two boards must be inversely proportional to the lift-coefficient, i.e.

$$\frac{A_3}{A_2} = \frac{C_{L_2}}{C_{L_3}}$$

At $\alpha = 30°$ the area of B 3 must be approximately 12% greater than the area of B 2, but at the same time its L-D ratio is approximately 7% better. During this comparison the speed is of course kept constant.

Proceeding to Diagram 3, we find that based on constant lift-coefficient (or constant area) the otterboard B 2a with a leading edge slot is approximately 25% better than B 2 at $\alpha = 30°$. Comparing B 2 a with the rectangular otterboard B 1 of Diagram 2 we find that on a constant area basis, the board B 2a at $\alpha = 30°$ is approximately 80% better than B 1. The corresponding angle of attack of B 1 is approximately 39°.

In connection with Diagram 6 it may be observed that the maximum lift-coefficients are smaller than those of the open water tests, and further that maximum lift is reached at a smaller angle of attack. Both these results are in agreement with the observations of Dickson on tests by Gawn and Yakovlev.

Comparing with Diagram 2 we find that at an angle of attack of 30°, the L-D ratio of B 2 is slightly better under bottom conditions than under open water condition. The same CL can of course be obtained at a lower angle of attack, i.e. 27°, and at this point the L-D ratio is still much better.

The APE-II measurement system

Devices for measuring were also evolved and the latest specifications for those devices are here given:

The present measurement arrangement—the APE-II—is based upon a system used for experiments in the autumn 1962. Both systems were developed at the Norwegian Central Institute for Industrial Research. The first system was based upon the use of one standard 10 mV multipoint recorder and a 3-single-wire connection between ship and trawl. The experiences with this system showed that such a system can be used when handled with care. It is however very sensitive to water leakage. (See diagram.)

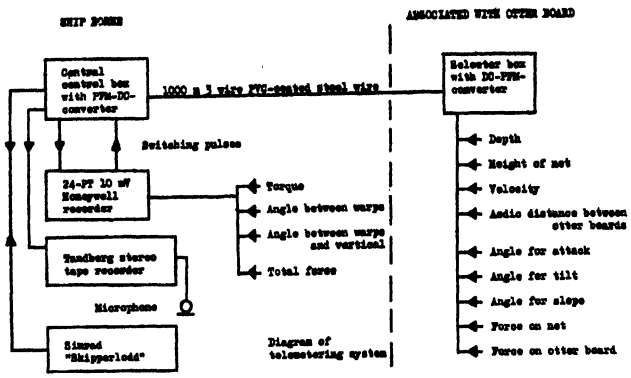
1. All transducers at the trawl had their separate stabilised power supply built into the transducer.

For battery economy these supplies can be turned on/off electronically by switching pulses from the ship.

2. The selector-box contains two alternative systems:

(a) straight DC, as original

(b) a digital system, using pulse frequency modulation.



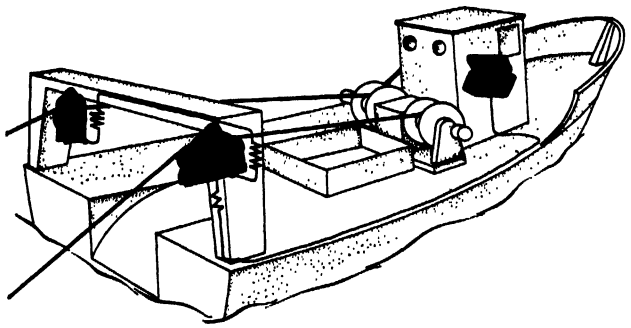


Fig. 5. APE-telemeter towing block.

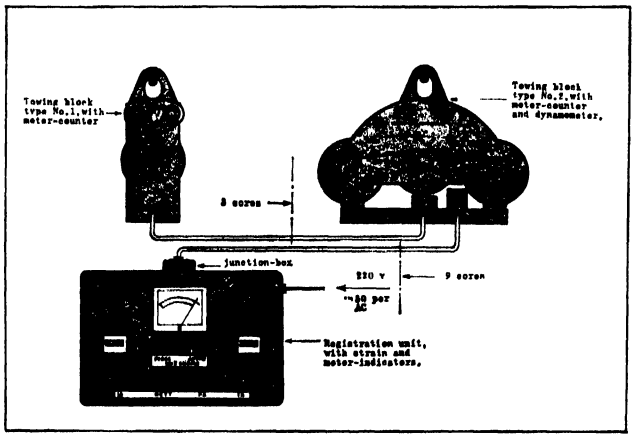


Fig. 5a. APE detail of telemeter towing block.

3. The three separate steel wires combined to one 3-wire PVC-coated cable.

4. Because of the pulse frequency modulation and the inclusion of a few other features such as audible signal indicator a separate signal control box has been inserted before the multipoint recorder.

5. Provision was made for recording the pulse frequency modulated signal on magnetic tape to follow the rapid oscillations or changes of variables, which the multipoint-recorder could not trace. The second channel of the recorder for oral indications or comments.

6. Measurements which are performed on board the ship by-pass the control-box and goes directly to the mV recorder.

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Fishing Methods and Gear Research Institutes: Their Organisation and Scope

by
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Abstract
Until recently the development of fishing gear and methods was done solely by the fishing industry. The increasing complexity of fishing, which is due to changes in fishing conditions and the general technical development, is making such development more and more difficult, expensive and risky for most fisheries to carry on on their own. Many governments have therefore started or are considering supporting development in fishing gear and methods by financial subsidies and through the services of specialised research institutes. The paper gives detailed recommendations for the scope of work and the organisation and set-up of a Research Institute for Fishing Gear and Methods. These recommendations are based on several decades of practical experience in the Federal Republic of Germany. The recommendations are meant to cover the subject comprehensively. They include the required facilities and the problems of staffing. The main task of a Research Institute for Fishing Gear and Methods is considered to be the improvement of existing fishing gear and methods, and the development and introduction of new ones. The growing need for international collaboration and co-ordination of efforts is emphasised.

Institut de recherche d'engins et méthodes de pêche: Organization et portee

Résumé
Jusqu'à ces temps derniers, le développement des méthodes et engins de pêche a toujours été mené par l'industrie de pêche elle-même. Le changement survenu dans les conditions de pêche et le développement technique général ont accru la complexité des opérations de telle sorte qu'il devient de plus en plus difficile, coûteux et risqué pour l'industrie de continuer à le faire. Certains gouvernements participent déjà au développement des engins de pêche—d'autres envisagent de le faire—par une aide financière et par l'organisation d'Instituts de recherche spécialisés en la matière. L'étude communique des recommandations détaillées sur l'importance du travail et l'organisation d'un Institut de recherche sur les méthodes et engins de pêche. Ces recommandations sont basées sur plusieurs décades d'expériences pratiques effectuées en République Fédérale d'Allemagne; elles couvrent entièrement le sujet et traitent également des installations et problèmes de personnel. Le but principal d'un Institut de recherche de ce genre est l'amélioration des méthodes et engins de pêche existants et le développement et l'introduction de nouveaux engins et de nouvelles méthodes. La nécessité d'une collaboration internationale et d'une coordination des efforts y est soulignée.

Institutos de investigacion de métodos y artes de pesca: Su organización y finalidades

Extracto
Hasta recientemente el perfeccionamiento de los métodos y artes de pesca lo realizaba exclusivamente la industria pesquera. La creciente complejidad de la pesca, debida a cambios en las condiciones y adelantos técnicos generales hace cada vez más difícil, costoso y arriesgado para armadores individuales introducir las propias. Debido a ello, muchos gobiernos han iniciado o examinan la posibilidad de facilitar la mejora de los artes y métodos de pesca mediante subsidios en metálico y la prestación de servicios de institutos especializados en la investigación. El autor hace recomendaciones referentes a las finalidades de la labor y organización de un instituto de investigaciones de métodos y artes de pesca. Se basan en la experiencia práctica adquirida durante varias décadas en la República Federal Alemana y su finalidad es abarcar toda la materia, inclusive los medios y personal necesarios. Se considera que la principal labor de tal instituto consiste en mejorar los métodos y artes de pesca en existencia y perfeccionar e introducir otros nuevos. Se pone de relieve la necesidad creciente de colaborar sobre el plano internacional y de coordinar los esfuerzos.

UNTIL recently the development of fishing gear and methods was based solely on the experience and efforts of practical fishing. The aim of these efforts was always to improve the economy by increasing catches while reducing costs and labour. Most fishermen are still trying to improve their gear and methods by applying modifications. Due to this simple empirical and uncoordinated approach of many groups and individuals, technical development has been rather slow.

Nowadays the fisheries of many countries are faced with the growing difficulties of longer distances to the fishing grounds, decreasing fish stocks and higher demand for quality products. More and more this limits the fisherman's possibilities—and those of the fishing companies—of introducing innovations without taking too serious economic risks. Consequently many countries have started to support their fishing industries by subsidising technical development. Furthermore, it has been found that it often is difficult for a fishing industry to conduct and evaluate trials and experiments on its own, even when the costs are borne by the Government. Further difficulty is met in recording and evaluating results obtained elsewhere for industry use, as well as distributing these results for the benefit of others. In view of this situation, the Governments of several countries have established governmental institutions for

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The variables included in the system are:

1-3 three angles on the otterboard,
3-4 two forces at the otterboard,
5 depth,
6 height of net opening, measured by differential pressure,
7 distance between otterboards,
8 relative velocity at the otterboard,
9-10 two warp-angles at deck,
11 total towing force,
12 torque on the propeller shaft.

The towing blocks (see Figs 5 and 5a) were designed to give information concerning the load in warps and the length of warps. They were dimensioned like ordinary trawl blocks and were of very robust construction and water and shock proof.

fishing methods and gear research. These are either individual institutes, or branches or sections of existing fisheries institutes.

2. Tasks and duties

In the following compilation of the proposed tasks and duties of such an institute, an attempt has been made to take into account everything related to catching collecting fish and other sea and freshwater products. This ranges from detecting and locating fish, to landing it. It is suggested that such an institute should put main emphasis on investigations of fishing techniques, and it will depend upon the particular conditions as to what extent the field of work of a certain institute will have to be devoted to the other subjects. In general, the work of a Research Institute for Fishing Gear and Methods should be concerned with the following main subjects:

(a) Textile materials for the production of fishing gear
(b) Manufacture of netting
(c) Non-textile materials and equipment for the manufacture of fishing gear
(d) Treatment and maintenance of fishing gear
(e) Design and construction of fishing gear
(f) Fishing techniques
(g) Location and detection of fish
(h) Biological problems connected with catching fish
(i) Mechanisation of fishing gear and methods
(j) Correlation between fishing boats and fishing techniques.

The above sequence of subjects was made up according to practical considerations and should not be taken as being in order of value.

2·1 Textile materials

This item includes all materials used for the manufacture of twines, netting, lines and ropes. In modern fisheries these can be natural or synthetic fibres, or metal wires. The Institute would not be concerned with basic investigations of the fibres, but would restrict its work to the products made from fibres, i.e. twines, cores, lines and ropes. The determination of the property of net materials is meant to enable the best choice of material for specific purposes as well as for the appropriate substitution of one material for another, e.g. natural fibres versus synthetic fibres. For such investigations the following properties will be of main importance. They all should be determined with the material in wet condition.

(a) Physical tests
  (1) Breaking strength
  (2) Extension
  (3) Stiffness
  (4) Abrasion resistance
  (5) Weight and sinking speed
  (6) Diameter
  (7) Surface roughness
  (8) Variations in length
  (9) Reaction to temperature
  (10) Reaction to light
(b) Chemical tests (11)

These tests would mainly be concerned with the resistance against tar products, oils, fuels, etc., particularly of synthetic fibres.

(c) Biological tests
  (12) Resistance to rotting
  (13) Resistance to macro-organisms (particularly crustaceans and larvae of insects)
  (14) Resistance against fouling (particularly important for gear left in the water for long periods)
(d) Workability tests
  (15) Processability of net materials
  (16) Ability to absorb colour and other treatments
  (17) Storability.

Some of these tests are habitually conducted by special institutes for textile research or by official material-testing institutes. They do not make these tests from a fisheries point of view, so the results are often of limited value for fisheries purposes.

2·2 Netting

(a) Manufacturing techniques for knotted netting
  (1) Net braiding by hand
  (2) Half-mechanised netmaking
  (3) Fully mechanised netmaking
(b) Manufacturing techniques for knotless netting
  (1) Twine-twisting technique
  (2) Raschel technique
  (3) Other techniques
(c) Testing of netting
  (1) Mesh size
  (2) Strength and extensibility of netting
  (3) Knot firmness and stability of mesh size
  (4) Weight of netting
  (5) Susceptibility to fouling or contamination by natural or synthetic materials found in water (coalescing of meshes).
  (6) Visibility of netting in water
  (7) Hydrodynamic resistance of netting.

Apart from the tests under "c", testing of netting may also include some of the tests listed under "Textile materials" (2·1).

2·3 Non-textile materials

Apart from netting, etc. made of textile materials, for the manufacture of most fishing gear, other implements are needed which often consist of other materials, the testing of which may be of value. They are for instance:

(a) Floats, buoys and sheering devices
(b) Sinkers and other weights
(c) Hooks and containers for bait
(d) Surface and underwater lamps

This list could be extended considerably, depending on the respective fishing technique (see 2·6).

2·4 Treatment and maintenance

Very often the netting used to construct fishing gear has to be treated specifically. These treatments may have the following purposes:

(a) Prevention of rot (net preservation in the original sense)
(b) Prevention of fouling by vegetable or zoological water organisms
(c) Stiffening of netting or twines to improve the workability or the catching efficiency
(d) Prevention of destruction by sunlight
(e) Colouring to improve catching efficiency
(f) Prevention of net destruction by other water organisms or during storage ashore.

2·5 Design and construction

The design and construction of fishing gear has so far been predominantly based on practical experience. To what extent engineering methods can be used for this purpose is still under discussion. The following means are available for the development, testing and evaluation of new fishing gear and methods:

(a) Model tests with
  (1) Small-scale model (e.g. 1:30) in model tanks
  (2) Large-scale models (e.g. 1:2) in open water
(b) Comparative fishing trials under normal commercial conditions with new or improved gear versus conventional gear
(c) Observation of the properties and behaviour of fishing gear in action
  (1) Direct observation by:
    (i) divers, diving chambers or submarines
    (ii) underwater photography
    (iii) underwater television
  (2) Indirect observation by:
    (i) Echo sounding
    (ii) Measuring instruments.

2·6 Fishing techniques

The main task of a Research Institute for Fishing Gear and Methods would probably always be the improvement of existing and the development of new fishing techniques. This would also include handling and operation techniques.

(a) Classification of fishing methods
  (1) Fishing without specific gear (e.g. collecting of shellfish, crabs, etc.)
  (2) Wounding methods (shooting of fish, harpooning)
  (3) Stupefying methods (fishing with poison, electrical fishing)
  (4) Hook and line methods
  (5) Trapping methods (traps, fyke, and stake nets, barriers)
  (6) Methods for jumping fish (particularly for mullet, salmon)
  (7) Bagnet methods (scoop, stow and gape nets in rivers and estuaries)
  (8) Dragging methods (dredges, beam trawls, otter trawls on the bottom and in midwater)
  (9) Seining methods operated from the shore or from boats
  (10) Surrounding and encircling methods (purse seines, lampara seines, etc.)
  (11) Dip or liftnet methods (including water wheels)
  (12) Falling net methods (castnets, cover pots, etc.)
  (13) Gillnet methods
  (14) Tangle net methods (with one or several net walls, e.g. trammel nets)
(b) Applicability of fishing techniques
  (1) Hydrographical conditions (water depth, current)
  (2) Meterological conditions (wind, waves)
  (3) Human prerequisites (number and quality of workers, co-operation in pair trawling or fleet operation)
(c) Influence of the fishing techniques on the quality of the catch.

2·7 Location and detection of fish

A prerequisite for commercial fishing is naturally the availability of fish in such quantities or concentrations that fishing will pay. Apart from the location of fish, i.e. the determination of areas where commercial fish schools are likely to be present, the Institute suggested here should mainly be concerned with the detection of fish, namely the spot plotting of profitable grounds or fish schools. On the accurate detection of these fish concentrations or schools, the rational selection of the fishing gear and mode of operation can be based. For fish detection the following ways and means are available:

(a) Observation of certain phenomena from the fishing boat (direct observation of fish and fish schools, behaviour of birds or other animals)
(b) Sensing lines and other implements derived from these observations
(c) Observation from aircraft with communication to fishing boats or fleets.
(d) Observation of typical fish smell (probably commercially utilised only in the sardine fishery in the Mediterranean off the African coast)
(e) Observation of biological underwater sound (many fish and shellfish produce specific noises)
(f) Echo sounding and echo ranging
(g) Underwater photography and television.

2·8 Biological problems

As was already mentioned under 2·5 (c), the direct or indirect observation of fishing gear can help to determine the effects of modifications. Direct observation is also particularly suitable for observing the reaction of the fish towards the fishing gear and thus to find means for improving the catching efficiency.

(a) Behaviour of fish
  (1) Behaviour of fish schools
  (2) Development of means for attraction and repulsion (particularly optical, acoustical and chemical baits, use of electricity).

Furthermore the suggested Research Institute for Fishing Gear and Methods will have to be concerned

with the conservation of fish stocks, in particular as regards the influence of the different fishing techniques on the fish stocks.

(b) Population dynamics
  (1) Influence of fishing on the fish stock
  (2) Fishing methods and selectivity of fishing gear and methods.

2·9 Mechanisation

The growing difficulties in many countries of obtaining enough suitable fishermen make it increasingly necessary to mechanise fishing operations. For this development, no general scheme can be given. The development of the North-west European trawl fishery from sidetrawling to sterntrawling with a chute is one illustration that basic improvements and developments can be achieved by the team work of fishermen, fishery technologists, mechanical engineers, and shipbuilders. Another example is the conversion of purse seining from the two-boat technique to the one-boat technique with powered block.

2·10 Correlation between fishing boats and fishing techniques

A fishing boat should be more than just a platform from which any fishing method can be applied somehow. Intensive commercial fishing requires specialised boats which preferably should be equipped for the efficient operation of more than one fishing method. This demand leads to the necessity of good co-operation between fishermen, fishery technologists and shipbuilders. There are two main items which require attention:

(a) Best adaptation of the fishing boat to the intended fishing methods
(b) Best adaptation of the deck layout and auxiliary gear to the respective fishing methods

These last items are already near the border of the suggested scope of work for a Research Institute of Fishing Gear and Methods. However, all fishery research institutes and the Institute for Fishing Gear and Methods would have the strongest need for good co-operation and co-ordination with naval architects and shipbuilders.

3. Staffing

One of the main problems connected with the establishment of a Research Institute for Fishing Gear and Methods will be to find qualified professionals, because in most countries there is, so far, no special education for this type of work. According to experience so far, it appears advantageous to train fishery biologists who are interested in technical problems rather than mechanical engineers, textile engineers, shipbuilding engineers or chemists for the specific tasks of research in fishing gear and methods. There are fewer difficulties in finding suitable assistants because the education and training of specialised textile, biological and chemical assistants is more or less adequate. The Institute will further be in need of skilled labourers for metal and woodwork, because of a variety of measuring and other instruments which would have to be constructed and maintained. Since an important part of the Institute's work will be devoted to practical fishing trials, assistants trained as fishermen and netmakers will be needed.

All this personnel must be able to work efficiently at sea under difficult conditions. The ability of smooth collaboration with fishermen is indispensable.

Naturally, not all the subjects listed above will need specific personnel, but the same scientist could be in charge of several. There are many ways of arranging the distribution of work in such an Institute as regards staff and facilities, and the actual set-up will largely depend on the requirements of the specific fishing industry which this Institute is meant to serve.

4. Buildings and equipment

It was tried to make the following layout of the working facilities comprehensive. This suggestion should, however, not be taken as binding. There are naturally other possibilities of co-ordination and collaboration which may be equally efficient and would require a modified set-up.

4·1 Textile laboratories

(a) Climate conditioned testing laboratory for net twines, with breaking strength testers, abrasion testers, flexibility testers, etc.
(b) Test laboratory for lines and ropes, with breaking strength tester having a measuring range of up to about 20 tons or more.
(c) Laboratory for biological tests, (with installations for aquaria and a waterproof floor with drainage)
(d) Laboratory for mould and soil rotting tests. In this room there must be provision for temperature and humidity control (29°C ± 1°, humidity 60-100%)
(e) Netmaking workshop for the construction of fishing gear
(f) Workshop with various types of net-making machines, rope-making machines, plaiting and braiding machines, etc.
(g) Storeroom for fishing gear and net materials. This room must be dry and have facilities to keep out light.

In addition to these laboratories two outposted stations are needed.

(h) Station for testing resistance of different materials against weather influences. (This station could possibly be placed on the roof of the Institute)
(i) Station for testing against rotting and fouling. (This station could be at a suitable spot on the sea coast, or on a river or lake.)

4·2 Chemical laboratories

(j) Analytic laboratory to analyse tanning substances, metal compounds, oil, etc.

(k) Chemical laboratory for general purposes such as experiments on net preservation
(l) Conservation and preservation plant for the treatment of netting and fishing gear on a larger scale. This room must be equipped with large heated drums and other containers for tanning, colouring and dyeing
(m) Storeroom for preservation materials and chemicals.

In addition to these indoor laboratories, outside facilities are needed, namely:

(n) Covered drying space for nets and ropes. This should preferably be close to the conservation and preservation plant.

4·3 Physical laboratories

(o) Laboratory for precise mechanical work concerned with observation and measuring equipment
(p) Mechanical workshop with tools and equipment for metal and woodwork
(q) Test-stand and workshop for marine engines and other motors
(r) Tank for model tests
(s) Echo-sounding laboratory
(t) Storeroom for measuring instruments and other auxiliary equipment such as rubber rafts, outboard engines, etc. needed for outdoor trials.

4·4 Biological laboratories

(u) Laboratory with aquaria for the investigation of fish behaviour
(v) Physiological laboratory specially for electrical fishing
(w) Large aquarium (round basin) for investigations of the behaviour of fish schools.

Apart from all these laboratories, the usual auxiliary rooms will be needed; such as, room for analytical balances, drawing room, photographic laboratory, library, registry, administration and conference room with facilities for showing slides and films. Furthermore each scientist should be provided with a separate small room near his laboratory.

In this context the need for a research vessel must be mentioned. Experience so far has shown that investigations in fishing gear and methods at sea are difficult to combine with biological and oceanographical investigations while it is comparatively easy to have a combination with fish-processing investigations. The research vessel should be basically a fishing vessel of the type and size of the commercial fishing boats whose needs must be served. For carrying special measuring equipment, motorised rubber boats have been found most suitable.

5. Co-operation with other institutions

The Research Institute for Fishing Gear and Methods will have to collaborate closely with other scientific institutions. The scope of work of fishing gear and methods research is however already so widespread and the work involved has become so expensive that many problems cannot efficiently be tackled any more on a national basis. Consequently, the collaboration with fisheries institutions of other countries becomes more and more important. To facilitate this collaboration and also the co-ordination of efforts, a number of agencies, societies and working groups are available such as the International Council for the Exploration of the Sea (ICES), the International Council for the North-west Atlantic Fisheries (ICNAF), the Food and Agriculture Organisation of the United Nations (FAO), The International Organisation for Standardisation (ISO), International Working Group for One-boat Midwater Trawling (APE or IF).

Discussion on Gear Research

Mr. W. Dickson (U.K.) Rapporteur: Kawakame's paper sets out pretty clearly the Japanese ideas on model testing. In this many rules are set up to obtain similarity between the model and the full-scale net. It is not always possible to obey all these rules and that is where difficulties start, particularly in relation to a desirable speed of towing the model. Dale and Moller give an interesting report on the testing of model trawl boards, oval and slotted.

Crewe's paper on the big comprehensive tests by Saunders Roe starts at the ship and works towards the trawl. His Figs. 8, 9 and 10 are very useful because they show how the drag of the gear matches the propeller thrust for a range of rpm as calculated from thrust curves. A heavier gear will have a steeper slope across these curves. If you know a net has been towed by another ship at four knots and gave a drag of seven tons you can tell right away what rpm's you need to drag that gear at four knots. Your own propeller characteristics and engine power curves will show whether your boat is capable of doing it.

By measuring the warp tension at the surface and at the otter boards and by measuring the warp declination at the surface and at the otter boards it becomes possible to build up a theory for warp shape and drag. The general finding was that the actual drag of the warps was 50 per cent greater than the drag as it would be calculated from the warp imagined simply as two cylinders running between boards and ship.

Armed with that theory of warp shape it can be decided how much of the otter-board weight to lift off the bottom and how much to let rest on it. That is determined by the tension in the warp and the angle at which it approaches the bottom. The warp length is chosen to get these two factors correct in relation to the weight of the otter board and that is the significance of Figs. 13 and 14.

It is a question of how much of the otter board's weight ought to rest on the bottom for it may either profit from ground shear or lose by it. It depends on whether the ground is hard or soft. Up to 25 per cent of the shearing force on the board can be due to ground shear.

Crewe also discusses the merits of cambered doors versus oval doors and settles for the cambered ones. Here it is noticeable what advance has been made since the last Congress. Hydrodynamic facts on otter-board performance have been produced from several sources so that calculations on net spread can now be made. As the warp is curved in the horizontal plane it means that the real otter-board spread is some

15 per cent up on the spread as measured by the warp divergences at the ship. For every value of spread of a headline of fixed length there is an appropriate lead-in angle which the wing and its spreading wire must follow without discontinuity. Thus with the otter-board spread established, it follows that the net spread can be established. Roughly speaking that is the significance of Crewe's graphs 28 to 30.

Crewe also gives the drag of sheet netting at angles of attack of 90 deg down to zero with a range of drag coefficient of from 1·25 down to the residual value of 0·16. May I appeal to other workers measuring the drag of sheet netting to give their results in this dimensionless form. I believe that this diagram No. 36, taken in conjunction with the ideas of M. Verhoest concerning drawing the developed area of a net and so knowing the angle of attack of each bit of it will, within the next few years, lead to a significant step forward in the calculation of trawl drag.

But it may not be quite so simple because Hamuro's paper gives different water speeds for inside and outside the net. In one case he gives 3·5 knots for the towing speed and a water speed of only 2·7 knots a couple of metres behind the footrope. That seems a very big difference to me—has anybody any confirmatory results? By improved net design he apparently cuts down the difference to less than 10 per cent at which figure it seems fair to say that there is not a big spill or form drag, if you like to call it that, and the bulk of the drag then arises locally at the netting. Farther aft in the region of the codend it is fairly certain that the waterflow through the meshes is at considerably less than the towing speed. The American underwater television film and our cine films show fish swimming along rather lazily in the codend when the towing speeds were such that in a full flow their swimming speeds would most likely have been exceeded. Permanganate crystals dropped in a towing tank show the tendency of water outside the net in the region of the model codend to swirl and follow the codend.

Crewe also shows in Fig. 37 that by doubling the headline height of a net its drag rose from 4·1 to 4·9 tons—a rise of 20 per cent—not big, but very significant. Now, can the necessary power be better spent on that extra headline height or on achieving extra spread, extra net size, or even speed or some combination of these, possibly even at reduced speed? Those are practical questions.

Von Brandt's paper on fishing methods and gear research institutes is set out with his usual thoroughness. In it and in the Norwegian organisational plan of Dale and Moller there might be more emphasis on what I would call technological economics—the sort of thing the Poles have been doing in their choice of boat types and fishing methods, but carried over instead to fishing gear and methods. Von Brandt says: "According to experience so far it appears advantageous to train fishery biologists who are interested in technical problems, rather than mechanical engineers, textile engineers, shipbuilding engineers or chemists, for the specific tasks of research in fishing gear and methods." This may be the experience in Germany but one American paper gives a hint of a different approach. I know that it has been for me a most exhilarating experience to work with a team comprising biologists, mathematicians, hydrodynamicists, physicists, engineers and statisticians and not only these but with some of the Humber skippers and ex-skippers who have made a real contribution to the work of the team.

Mr. Dennis Roberts (U.K.): I think the world has opened up into two communities in fishing. The first comprises those who want to catch more fish to provide more food for their people and the other—the community to which I belong—has to provide commercial fish. My problem is not to catch more fish but to catch more fish more cheaply and in a commercial way. To do that we have planned a mechanised ship, the *Ross Daring*, and with the increased efficiency we conceive will be achieved, we have been able to reduce crew. Some new and advanced instruments such as the fish-finding devices mentioned yesterday may help us catch more fish but it won't help us catch more fish more cheaply. It represents an additional expense and my problem is to achieve economy in operation.

Mr. P. R. Crewe (U.K.): I will contribute a few remarks on our broad objectives. Our contract with the White Fish Authority required us to make a general engineering design investigation of Arctic bottom trawl gear, including a mathematical analysis of its performance characteristics, leading to the design and development of a gear having a headline height and mouth width greater than that of the Granton type of trawl generally used by British distant-water trawlers.

The specified objectives could be achieved without reference to problems of fish behaviour, and we were not required to concern ourselves with the latter. However, we naturally considered that it was most important to bear the available information on fish behaviour in mind. This, in the main, comprised two observations: first, the practical experience of the industry that catch is increased as the otter boards are moved farther and farther ahead of the net, and, second, indications of fisheries' laboratory experiments that fish do not appear to react to gear until it is extremely close to them, unless they can see it.

Within this scope, we first studied the problem of headline height, and related it to the characteristics of the leg and sweepwire system, the headline floats and the design of the net wings. Mr. Denis Roberts has explained that a major problem for the British fishing industry is to catch a given amount of fish more cheaply. In view of this and, in particular, because of the importance placed by the industry on keeping the area of net to be mended as small as possible, and the water resistance of the gear low enough for most existing sidetrawlers to tow it, we did not especially favour solutions of the type described by Mr. Hamuro in Paper 2, where a net having a surface area about 2·5 times that of the Granton trawl, requires over 50 per cent more horse-power to tow it at the same speed.

Instead we first considered how to achieve a given headline height and mouth width by using a relatively moderate area of net, with wings and bridles spread to a larger angle than the value of about 16 deg appropriate to the Granton trawl.

In order to keep resistance as low as possible, methods of refining the otter boards were studied, and model tests were made of many different shapes. These involved measurements of sideforce and drag with the boards both upright and heeled over, and also when tilted so as to bring the fore or aft end of the sole plate off the ground. In addition towing tank tests of the stability of boards during shooting were made.

In view of the broad scope of our studies it was necessary to establish mathematical methods for predicting gear performance over a wide range of angles between the wings and sweepwires, and the direction of motion. In fact some of the graphs in the paper cover the overall academically possible range from 0 to 90 deg.

Furthermore, the stability equations for the otter boards had to be sufficiently general to cover aspect ratios from below one-half to above two. It was also necessary to consider the effect of the ground forces that act on an otter board that is not free flying, and also to study the behaviour when the board is lifted off the bottom, and the ground forces are no longer there.

Detailed studies of the behaviour of warps were made so that the maximum information could be deduced from measurements of warp load and angles, made by instruments attached to the warps in the neighbourhood of the block.

The mathematical performance prediction methods have been developed to the point where deductions of sea-bed behaviour, based on the readings of the instruments at the block, are in gratifying agreement with records provided by self-contained recording instruments, mounted on the sea-bed gear.

Furthermore, satisfactory comparisons have been made between towing pulls measured at the block, and values estimated from the resistance and propulsion characteristics of the trawler hull, the known engine rpm, and the ship's log speed. This can greatly reduce the necessity of measuring towing pull directly, since, of course, a single family of curves exists for a given ship, irrespective of the gear being towed. Allowance must, however, be made for windage on the ship's superstructure.

The estimated lengths of warp, of any chosen diameter, required for a gear of a given drag, at any towing speed or depth of water, agree very well with the rule of thumb practice of commercial skippers.

I have mentioned some of our methods for designing gears to any given engineering specification. The problem is to decide what the details of the specification should be.

Information on fish behaviour in relation to the catching power of trawl gear, given in various papers, seems to me to show that increasing net mouth area, and the distance between the otter boards, does not in itself guarantee anything like a proportional increase in catching ability. Whether fish behaviour characteristics favour a large net, with a small angle of the sweepwires, or the reverse, or some compromise, does not appear to have been established by these papers.

However, irrespective of what the answer is, the general methods of design analysis, and hydrodynamic test results, of the type referred to in my paper, are proving to be very useful in the design and development of trawl gears to meet various specified engineering requirements.

It may well be that the best way to solve fish behaviour problems is to design by these methods a range of gears so chosen that comparative fishing trials with them will have a sporting chance of disclosing what features will give us the greatest advantage over the fish.

Dr. J. N. Carruthers (U.K.): What I don't understand is why when nets are tested, care is not taken to study the variation of the currents on the bottom. They can be enormously different from hour to hour. The skippers who are fishing just do not know how these currents are setting and the variations can be quite considerable. It puzzles me to understand how the hydrodynamicists disentangle the influence of the sea from the other influences that they notice and which they are investigating. This is a matter which is particularly important when you come to midwater trawling. What we have to know is what the sea is doing to the net before we can make inferences regarding the actual behaviour of the net.

Mr. Crewe said that when trawling at four knots he thought that the bottom current would have relatively little importance. He hoped, however, that it would be possible in future to give more attention to the point made. They had put speedmeters on the trawl nets but had not so far got much information. The point would be pursued.

Dr. Miyazaki (Japan): When a fishing net has considerable dimensions it is impossible to observe simultaneously the configuration and performance of every part under water. We therefore often undertake model net experiments to determine the hydraulic functions of a net that can be made equivalent with those of a full-scale fishing net. These model nets are made on principles laid down by Tauti in 1934. His essential hypotheses for establishing the hydraulic relationship between two nets were: (1) that the elongation of twines of both nets is negligibly small, (2) netting twines of both nets are perfectly flexible, (3) that change in the form of the net shall take place slowly enough to keep quasi-equilibrium of a net under study among external forces acting on every portion of the net. Models were therefore built to satisfy those requirements. Numerous experiments showed that model nets so built enabled gear technologists to obtain results which were well applicable to a full-scale net. Such models were particularly useful for observing the effects of currents on the setting of the net and gave a general idea of how the net actually behaves under the water.

Dr. Bosch (Netherlands): From Bombeke's paper one gets the impression that braided nylon is superior as regards drag to other nylon twines of the same diameter. Could this be explained by the difference in the actual diameter? Was that confirmed by the actual handling of the net at sea? In connection with such tests he would recommend they be carried out in water after prolonged immersion of the twines and, secondly, that the dimensions should be measured under test conditions especially with regard to tension and water absorption before and after the tests. These results should be presented in the form of drag coefficients.

Dr. Schärfe (Germany), agreed thoroughly with Dr. Carruthers that the currents encountered in trawling and testing were most complicated. In their experiments they tried to find areas where the currents were as small as possible such as in the Baltic. The fact that the currents were in different layers and also changed quickly made it practically impossible to work in certain conditions. They had to find gear which would operate efficiently in a great many different conditions. To do that, they would have to avoid aiming at the last few percentages of efficiency. They had to have gear that would adapt itself to change and be reasonably good for overall fishing.

Dr. W. M. Chapman (U.S.A.): Our view is that we have to catch fish for profit. If we can do this by increasing the volume of fish or by decreasing the unit cost it is all the same to us. What we are discussing comes back to economics. We look to technical advances and stimulate research in various fields and then management must grasp ideas from those advances and research which can be put into the economic context and work. That is not always left to management. In our tuna fisheries it has been the adaptation made by adventurous boat owners and fishermen that has been the more important factor than the adventurousness of management. The adoption of tuna purse seining in the Eastern Pacific was stimulated by the absolute economic desperation of the fishermen. They were going broke under the former cost conditions and they undertook adaptation to the power block plus the nylon purse seine as an act of absolute desperation. The man chiefly responsible reckoned that if he did not take this gamble, within three years he would be bankrupt; so he raised 250,000 dollars and put it in a purse seiner and converted his boat to purse seining. He was lucky and the method worked.

On Dr. Carruthers' point about the temperature and condition of the sea he admitted there was a condition in the West African waters which affected the success of purse seining. Here was a case where an extremely efficient technological method must await further advances in oceanographic research in that area before it would be economically possible to apply it there. They had to investigate the influence of the thermoclime in West African waters. There was a condition in the

tropical seas where directly below the thermocline there was not only a layer of lower temperature water but also of lower oxygen content water. The theory that was being investigated in respect of the use of purse seining on tuna in tropical waters was that the tuna will not dive through a sharp thermocline into this colder and oxygen-deficient water for simple physiological reasons. Therefore if the net goes down to the thermocline you had a floor under the net as well as having a wall net round the fish. This looked as if it was proving to be the case. They were having difficulty in getting information on this question because there were very few tuna vessels which carried both a thermograph and a scientist capable of interpreting the results. They did, however, have some such work going on in the Eastern Pacific and it was possible to say that the theory appeared to be generally correct. Where this was of importance in the West African Area was that they had had extremely varying results in the use of purse seines for tuna, probably because of the depth of the mixed layer and as a result they had for the time being given up the attempt to use this highly efficient gear of purse seining in that area and had gone back to the relatively low type of efficiency gear of using live bait, because in the conditions it was the most economical fishing method for the time being. His point in making these comments was that they required to examine the full range of technological and scientific data as well as oceanographical information in order to make managerial decisions as how to catch both fish and dollars.

Mr. Dickson, summing up, referred to Mr. Hamuro's large Japanese net which was three times the area of the Granton trawl, and the sort of difficulties that the adoption of such a trawl would encounter in the Arctic where there were bad grounds. The alternative was adopt a net that was not very much bigger than the Granton but push up the angle at which the wings and the sweep wires presented themselves to the water. One of the difficulties of designing new otter boards with better lift to drag ratio was that it was not only a case of getting something to have a good lift once it was on the bottom. Such a design can lead to difficulties in shooting the net, and they had to resolve these two things—design a new otter board that would give a good lift and one that could be shot with some facility. The engineering side said that they could now design a net according to the specifications required. The real trouble was what should the specifications be. As to currents affecting the behaviour of gear, Mr. Crewe was right in saying that with the normal speed of trawling approximating four knots they would be less affected by tides than when towing speeds were slightly slower. Experimental testing of nets should certainly be done where possible where currents were small. They had noticed when comparing the results of tests taken on the Fladen ground, where the bottom was smooth, they got a much closer scatter in their speed and drag curves than they did in the Faroes where the tide was pretty fierce. The point made by Dr. Miyazaki as to the value of model testing of nets was good and here it had to be borne in mind that models of nets should be made flexible and simple so as to be identical with the principal net to which it related. Many people used twine that was far too heavy for model making and it gave a false picture of what was happening in the net. This was another case where they had to reach a reasonable compromise. Dr. Bosch's point as to the tensions of twine in sheet netting in relation to drag was sound in that twine tension could influence the drag of the netting. In tests on the drag of sheet netting it seemed to be agreed that results should be quoted in terms of drag coefficient. As to the point raised by Mr. Roberts we seem to agree that whether we want to catch more fish or the same amount at less cost, we should aim to do so with the smallest crews.

Trawl Gear Instrumentation and Full-Scale Testing

Abstract

This paper describes the instruments which were used in the trawl gear studies reported on in papers by Crewe (No. 65) and Dickson (No. 59). A market survey indicated that very few of the necessary instruments were readily obtainable and this work concerned the design, development and construction of suitable instruments. Instruments considered necessary to measure and if possible record continuously for proper understanding of trawl performance, configuration and behaviour to be obtained, are divided by the author into two groups, deck type instruments and underwater instruments. The instruments are fully described in the text and some 35 photographs and detailed engineering drawings are included. Deck type instruments included warp load meters, divergence meter, warp declination meter, warp heel meter, ship's speed log and control panel and recorders. Underwater instruments were designed for operation at all depths down to 300 fm. They included warp load cells, warp declination meter, otter board angle of heel meter, otter board angle of attack meter, board pitch meter, electronic spread meters Mark 1A and Mark 2, headline height manometer, trawl speed meters, and net twine load cells. In carrying out full-scale trials, the number and type of instruments used in any given haul depends on the particular aspects of the trawling behaviour or performance being studied. In general, however, the deck type instruments are used and complete records made for all hauls together with loading cells, in the warps immediately forward of the boards and in backstrops, and the headline height manometer. In many hauls the whole range of instruments with up to 10 load cells inserted in the cables were used. The author believes that a full range of instruments is now available, the data from which in full-scale tests of various trawls has proved invaluable in the development of basic theory relating to trawl gear design, and will in the future give further data of importance in the confirmation and extension of the theory.

Utilisation d'instruments dans les essais sur des chaluts de grandeur nature

Résumé

La communication décrit les instruments qui ont été utilisés au cours des études de chalut rapportées par M. Crewe (No. 65) et M. Dickson (No. 59). Une enquête avait révélé que, très peu des instruments nécessaires à ce travail étaient disponibles sur le marché et ce document concerne le dessin, le développement et la construction d'instruments appropriés. La parfaite connaissance du fonctionnement, de la configuration et du comportement du chalut nécessite des instruments pouvant mesurer et si possible enregistrer continuellement. Ces instruments, d'après les auteurs, peuvent être classés en instruments de pont et instruments sous-marins; ils sont complètement décrits dans le texte et illustrés de 35 photographies et dessins détaillés. L'instrumentation de pont comprend des instruments pour mesurer la tension, la divergence, la déclinaison des funes, les locks, panneaux de contrôle et les enregistreurs. Les instruments sous-marins dessinés pour opérer à des profondeurs allant jusqu'à 300 brasses, comprennent: des cellules de tension, de déclinaison pour les funes, des instruments pour mesurer la bande, l'angle d'attaque, le tangage des panneaux, des instruments électroniques pour mesurer l'ouverture horizontale, des manomètres pour mesurer l'ouverture verticale et la vitesse du chalut, et un tensiomètre pour fils du filet. Au cours des essais, le nombre et le type des instruments utilisés dépendaient des aspects particuliers du comportement et de la performance du chalut, et un tensionmètre pour les fils du filet. Au cours des essais, pont sont employés. Pour chaque opération, des enregistrements complets ont été faits avec des cellules de tension insérées dans les funes au-devant des panneaux, sur les branchons et sur le manomètre mesurant la hauteur de la ralingue supérieure. Dans de nombreuses opérations, tous les instruments avaient jusqu'à 10 cellules de tension insérées dans les câbles. L'auteur croit que toute une gamme d'instruments existe maintenant et les renseignements obtenus au cours d'essais sur des chaluts "grandeur nature" ont été d'importance capitale pour le développement d'une théorie de base concernant le dessin des chaluts, et que dans l'avenir, ces instruments donneront d'autres informations importantes qui confirmeront et étendront cette théorie.

Instrumentos para ensayar a toda escala artes de arrastre

Extracto

Describe la ponencia los instrumentos empleados en los estudios de artes de pesca de que se da cuenta en las ponencias de Crewe (No. 65) y Dickson (No. 59). Un examen del mercado indicó que muy pocos de los instrumentos necesarios se podian obtener con facilidad. Esta comunicación da a conocer el proyecto, construcción y perfeccionamiento de instrumentos adecuados. Los instrumentos considerados necesarios para medir y, de ser factible, registrar continuamente para obtener una comprensión clara del rendimiento, forma y comportamiento del arte, los divide el autor en dos grupos: los de cubierta y los submarinos. Se describen con toda clase de pormenores y se dan 35 fotografias y algunos esquemas muy detallados. Entre los instrumentos de cubierta están los medidores de la carga, declinación, inclinación y divergencia del cable, correderas, cuadros de mandos y registradores; los instrumentos submarinos se proyectaron para funcionar a todas las profundidades hasta 300 brazas y comprenden células de carga y medidores de la declinación del cable, medidores del ángulo de inclinación, del ángulo de ataque y del cabeceo de las puertas, medidores electrónicos de la abertura Mark 1A y Marck 2, manómetro de la altura de la relinga de corchos, registradores de la velocidad del arte, y células registradoras de la carga a que están sometidos los hilos. Al realizar los ensayos a toda escala, el número y clase de instrumentos empleados en cada lance dado depende de aspectos especiales del comportamiento o rendimiento del arte que se estudia. En general, en todos los lances se emplean los instrumentos de cubierta para obtener registros completos y también se usan células de carga en los cables immediatamente delante y detrás de las puertas y el manómetro de altura de la relinga de corchos. En algunos lances se emplearon todos los instrumentos, insertándose en los cables hasta 10 células de carga. Cree el autor que actualmente se encuentran instrumentos de todas clases, con los que en ensayos a toda escala de diversos artes de arrastre se han obtenido datos que han resultado valiosísimos en la formulación de teorías fundamentales relativas a las formas de los artes, y que en el futuro darán otros datos de importancia que servirán para confirmar y ampliar las teorías.

by
J. Nicholls

Westland Aircraft Ltd.
(Saunders-Roe Division)

1. LATE in 1958 the White Fish Authority with the financial backing of the British Trawlers' Federation and H.M. Government placed a Research and Development contract with Saunders-Roe Ltd (now the Saunders-Roe Division of Westland Aircraft Ltd), the ultimate object of which was the

production of a new trawl with increased headline height and spread to replace the Small Granton trawl as used by the distant-water fishing fleet.

It was obvious that for the efficient carrying out of such a programme a substantial range of special instruments was required. A market survey showed that very few of these instruments were readily obtainable, and hence the contract included the design, development and supply of suitable instruments.

This paper describes some of the instruments and their mode of operation and use in full-scale testing of trawl gear. It should be noted that patents have been taken out on some of the instruments.

2. RANGE OF INSTRUMENTS

The following parameters are those which it was considered essential to measure and if possible record continuously, to enable a full understanding of the trawl performance, configuration and behaviour to be obtained. Although some are of greater importance than others they are not given in order of importance but in order of location from the winch to the codend.

(a) Warp tensile loads at ship
(b) Warp divergence at towing block
(c) Warp declination at towing block
(d) Warp heel at towing block
(e) Ship's speed
(f) Loads in cables, i.e. warp forward of otter boards, bridles, headline, groundrope, etc.
(g) Warp declination at otter board
(h) Otter board angle of heel
(j) Otter board angle of attack
(k) Otter board angle of pitch
(l) Board spread, i.e. distance between the boards
(m) Netmouth spread
(n) Headline height
(p) Loads in the twines of the net
(q) Trawl speed

It is noted that the instruments divide into two main groups each with two sub groups as follows:

Group 1. Deck type instruments. (This designation simply means that they are used on the deck of the ship and not under water.)

1·1 Load measuring instruments.
1·2 Configuration (angle or distance) measuring instruments.

Group 2. Underwater instruments.

2·1 Load measuring instruments.
2·2 Configuration instruments.

3. BASIC DESIGN OF INSTRUMENTS

3·1 Deck type

It was decided that these should be of electro-mechanical type, with remote visual recording in the ship's laboratory.

Based on the experience of the Aberdeen Fisheries Laboratory, these instruments were designed to be used with Leeds and Northrup Type H Model S 0-12 mv servo operated strip chart recorders, these having a response of 1 sec for full-scale deflection and a chart speed of 0·5 inch per min. Of course any other recorder of suitable characteristics can be used.

3·2 Underwater instruments

It was decided that all the instruments should be designed for operation at all depths down to 300 fathoms.

While the very desirable ideal was to transmit all the information to the ship for visual recording so that at all times a complete running picture of what was happening to the trawl could be seen, it was concluded from a study of the state of the development of underwater telemetry that this was not practicable within the time and money available. The use of warps with multi-core electric conductors was also considered impracticable. The underwater instruments therefore had to be of a completely self-contained recording type.

Investigations were made as to which type of instrument—electric, electronic, or mechanical—would be most suitable and it was concluded that, apart from the electronic spread meters, mechanical type instruments offered the best solution.

As regards the recording, three types of chart were considered: circular, continuous strip, and drum charts. For reasons of both cost and space economy, drum clocks and charts were decided upon.

Of the many methods available for marking the trace on the chart, a heated stylus operating on heat sensitive paper was thought best. This method had the advantage of minimum stylus pressure combined with the fact that the recording was completely unaffected by the attitude of the instrument. One disadvantage was that an electric battery was required for stylus heating and this proved to be a difficulty in some instruments from a space point of view.

4. DECK TYPE INSTRUMENTS

4·1 Warp load meters

The complete equipment consists of the meter for attaching to the warp, a multi channel control panel or an individual control box, an inter-connection lead, a 6 V DC power supply, and a recorder.

The meter is designed to measure the load, up to a maximum of 10 to 11 tons, in a continuous warp of which the largest size allowed for is 3¼-inch circumference and is of the well-known 3-wheel centre deflected principle.

Many instruments of this type are made for a fixed cable diameter or are adjustable in discrete steps for other cable diameters and hence considerable errors in the indicated loads are induced by variations in the nominal diameter of the cables and by the additional changes due to wear and tear. These troubles have been overcome by incorporating a screw adjustment on the centre wheel which permits the meter to be used on cables ranging in size from 1⅝-inch circumference or less to 3¼-inch circumference and, what is very important, allows a zero adjustment to suit the exact size of the cable being tested.

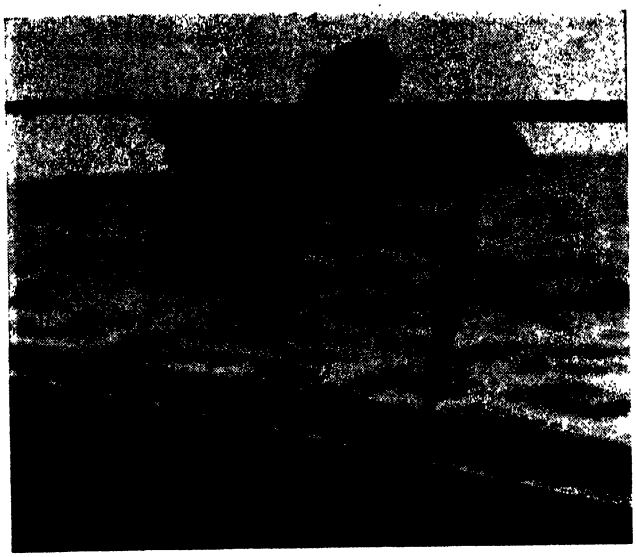


Fig. 1. Warp load meter (deck type).

The meter shown in Fig. 1 in use on a trawl warp, consists of a rigid beam with two fixed wheels, one each end, which rest on the warp, and a centre wheel on the opposite side of the warp. This centre wheel is removable to allow fitting the meter to the warp and is adjustable for the cable size and zero setting, and a definite deflection ($\frac{1}{2}$ inch) to the warp between the two outer wheels is applied through a lever-operated eccentric. The centre wheel adjustable and sliding mounting incorporates a strain gauged tensile link for measuring the lateral load, which has a definite relationship to the warp tensile load. The electrical strain gauges are standard Saunders-Roe $\frac{1}{2}$-inch foil gauges and have given complete reliability and trouble-free service over a period of four years with some 250 to 300 hrs recording.

The strain gauge bridge is designed for a 5 V DC power supply and as the output of the bridge is dependent on the voltage applied it is essential that this is kept constant. For this reason a nominal 6 V battery is used with a potentiometer and voltmeter in the circuit so that the bridge voltage can be set and maintained at the required 5 V.

The electrical system is shown in Fig. 2.

The output, approximately 11 mv for 10 tons warp load, is not linear with the warp load, due to the small deflections of the beam and crushing of the warp and varies slightly with warp size. A typical calibration curve using a $3\frac{1}{2}$-inch circumference warp is shown in Fig. 3. The reason for the scatter of the results was at first obscure but was found by careful and detailed tests. On individual calibration tests a complete cycle of loading gives a hysteresis loop of approximately $\pm$ 1 per cent about the mean, and this is also shown in Fig. 3; providing the meter is located in precisely the same position on the warp this is repeatable within about $\pm\frac{1}{2}$ per cent change in the mean line position. However, as the meter location on the warp relative to the spiral lay of the warp is altered so the slope of the mean line alters. The mean curve given in Fig. 3 is from 8 cycles of loading at differing

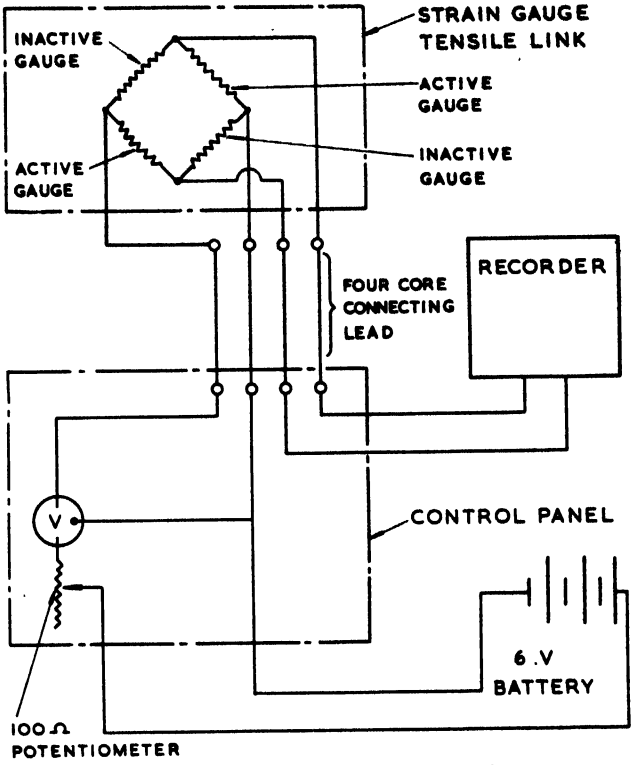


Fig. 2. Warp load meter (deck type) electrical system.

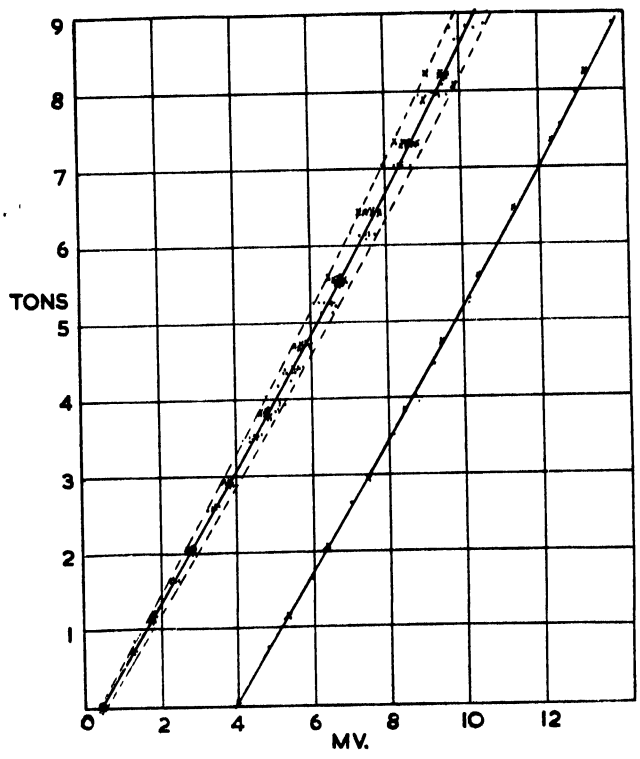


Fig 3. Deck warp meter calibration. Typical.

positions along the spiral and the upper and lower boundary points show limits of $\pm$ 6 per cent relative to the mean line. This variation is presumably due to the

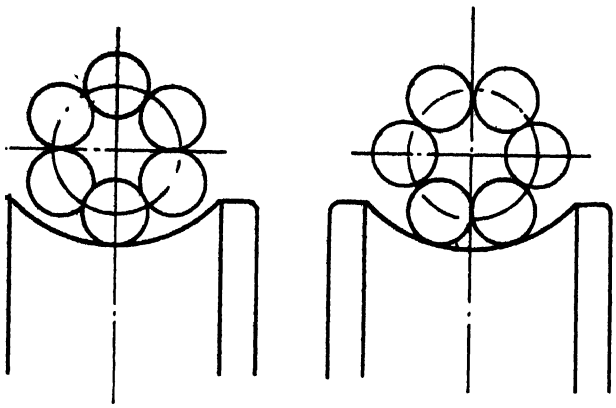


Fig. 4. Diagram of contact of warp on pulley, showing effect of spiral lay.

differing crushing deflections of the warp, see Fig. 4, altering the total warp deflections. However, the accuracy of ± 6 per cent is considered very reasonable in view of the fact that a large part of the variation is due to the inherent characteristics of the warp, although an improvement might possibly be obtained if separate sets of wheels, with grooves machined to fit snugly round the warp, were provided for each nominal size of warp.

It is noted that in full-scale tests the analysis of a number of hauls where the ship speed, tide, trawls, and bottom conditions were as nearly identical as possible, showed scatter of loads in the order of only ± 3 per cent. A typical recording is shown in Fig. 5.

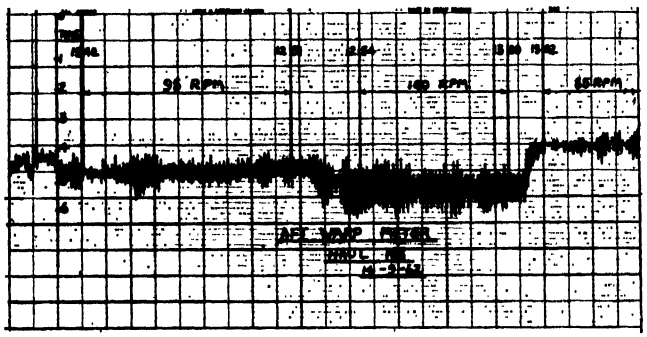


Fig. 5. Typical warp meter recording (deck type).

The meter, which weighs 44 lb, is very easy and simple to fit to the warp by two men and takes only 2 min or so even in fairly rough weather.

The rigid beam is of welded channel section in corrosion-resistant aluminium alloy. No trouble from corrosion has been found in the four years the instruments have been in use.

4·2 Divergence meter

This instrument is designed to measure the divergence angle of the warps at the towing block, but for convenience in interpreting the results is arranged to indicate the angle in terms of the spread in feet per fathom of warp aft of the block.

The meter, shown fitted to the warps in Fig. 6, consists of two tubes, nominally parallel to each other, and

Fig. 6. Divergence meter with declination and heel meters.

referred to hereafter as the warp tubes, each with two hooks for locating the meter on the warps. Their ends are connected by two spring loaded telescopic struts, the forward one of which is fixed rigidly at 90° to one of the warp tubes and is pivoted to the other warp tube. At this pivot a toroidal potentiometer is incorporated in such a manner that any angular movement of the warp tubes relative to each other causes a corresponding displacement of the potentiometer. The telescopic strut at the aft end is pivoted to both warp tubes. The telescopic struts and their pivots are arranged so that warping of the whole assembly, to allow for differential declinations of the two warps, can take place. In use the meter, as shown in Fig. 6, is placed on the warps, just aft of the towing block, with the hooks between the warps, the spring loading of the telescopic struts holding the warp tubes against the warps, thus displacing the potentiometer to the angle corresponding to that of the warps.

It should be noted that the instrument shown is made for starboard sidetrawling, and for port sidetrawling a meter of opposite hand is required to avoid the telescopic struts fouling the ship's side.

On the present instruments the maximum divergence angle of the warps which can be measured is 1·2 ft per fathom of warp (approximately 11½°) but could be modified if required, to measure larger divergencies.

The electrical system shown in Fig. 7 incorporates the measuring potentiometer and a zero setting potentiometer in the meter itself and the meter is connected by a plug-in 4-core cable to a control panel carrying a fixed resistance and a helical setting potentiometer arranged so that the same 6 V power supply as used for the warp load meters can be used and this gives an output of 1 mv for each ·1 ft per fathom of warp spread.

A setting and checking jig is supplied with the meter.

For all hauls, immediately prior to fitting to the warp and after connecting to the control panel, the meter is

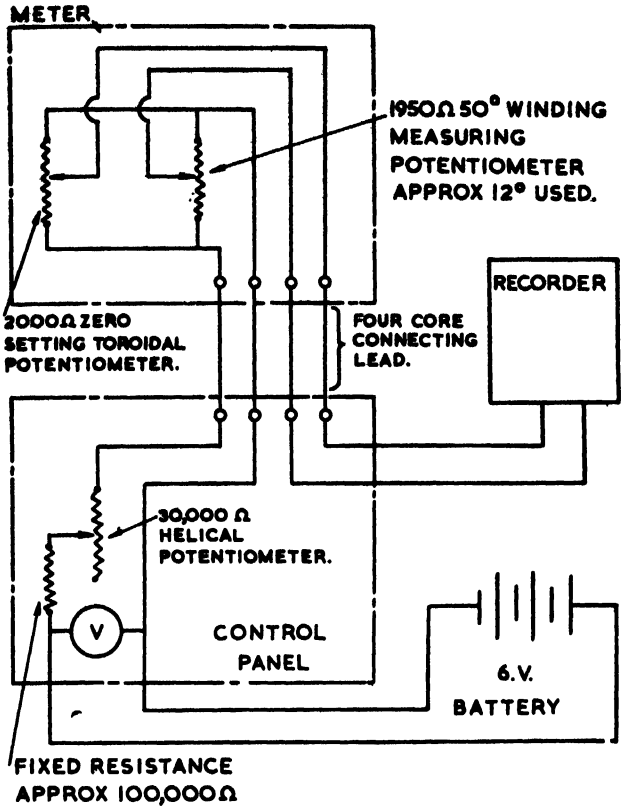


Fig. 7. Divergence meter electrical system.

set by placing it in the jig with the bars, representing the warps, parallel and in this condition the recorder should indicate zero. If this is not so, the zero setting potentiometer, access to which is given by removing the watertight cover, should be adjusted. It is noted that the zero setting potentiometer is fitted for two reasons, first as without it a true zero cannot be obtained on the measuring potentiometer due to the resistance of the end connection and secondly it enables any error caused by wear of the hooks due to warp vibration, to be corrected. The jig bars are then opened to the 1·0 ft/fm position and the control panel potentiometer is set so that 10 mv is indicated on the recorder. The meter is now set and ready for use.

At the end of each haul the meter is checked in the same way as above to confirm the satisfactory functioning of the instrument during the haul.

As regards accuracy, on basic calibration its error is not more than ± ·1 mv—equivalent to ·01 ft/fm of warp. Fishing with 400 fathoms of warp aft of the block this means an error of ±4 ft in the spread between the boards of say 200 ft. In practice even though the error may be slightly higher than indicated above because of vibration of the warps, this accuracy is considered very reasonable and acceptable.

A typical recording is shown in Fig. 8.

In fitting the meter to the warps, two pairs of hands are necessary. First, a retaining rope on the meter is securely tied to the ship and then if the towing block is on the level of, or only slightly below, the gunwale the meter can be closed by hand and placed on the warps with the hooks between the warps and then released so that the hooks engage underneath the warps. For use on ships where the towing block is well below the gunwale special tongs are provided which with the aid of an overhead block and tackle attached to the tongs to take the weight, lower the meter onto the warps and as the tongs are then released the meter opens and the hooks engage under the warps. Even in rough weather and using the tongs the meter can be fitted to the warps in a matter of 12 to 15 sec.

The meter is made throughout of stainless steel and, complete with the declination meter (qv), weighs 20 lb.

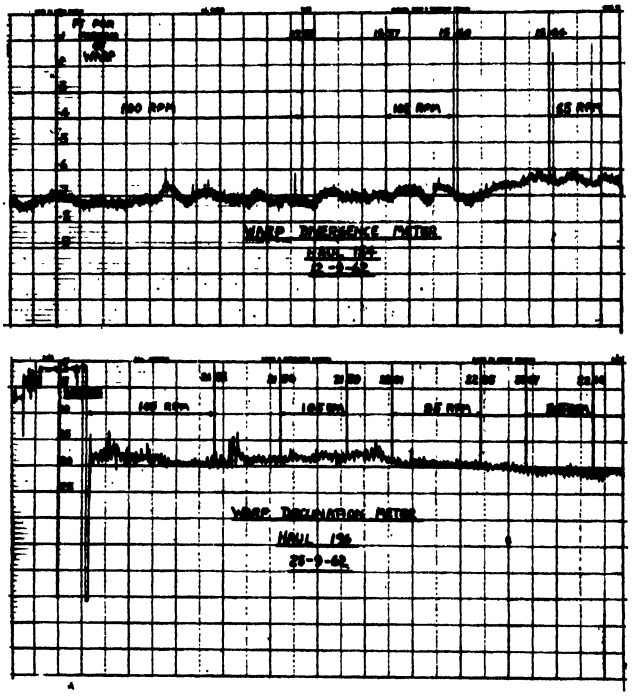


Fig. 8. Typical divergence and declination recordings.

4·3 Warp declination meter

The meter, designed to measure angles of declination from 0 to 45°, is set so that 1 mv output =5° declination. It consists of a simple pendulum the pivot of which is the spindle of a low friction toroidal potentiometer. The whole assembly is in a case filled with transformer oil to provide damping of the pendulum. For convenience of fitting to the warps, the case is bolted to the top of the divergence meter as shown in Fig. 6.

The electrical system shown in Fig. 9 incorporates the measuring potentiometer and a zero setting potentiometer on the meter these being connected by a 4-core cable to a control panel carrying a fixed resistance and a setting potentiometer arranged so that the same 6 V DC power supply as for the warp load meters can be used. Two accurately set stops are fitted, one at 0° and the other at 45° declination.

After bolting to the divergence meter and connecting to the control panel, the meter is set by first tipping the meter so that it is at a negative angle with the pendulum

on its 0° stop and checking that zero mv is indicated on the recorder. If it is necessary to adjust the zero, access to the zero set potentiometer by a screwdriver is by removing the plug in the top of the case. The meter is then tipped to a positive angle greater than 45° so that the pendulum is on the 45° stop and the setting potentiometer on the control panel is adjusted so that 9 mv is indicated on the recorder.

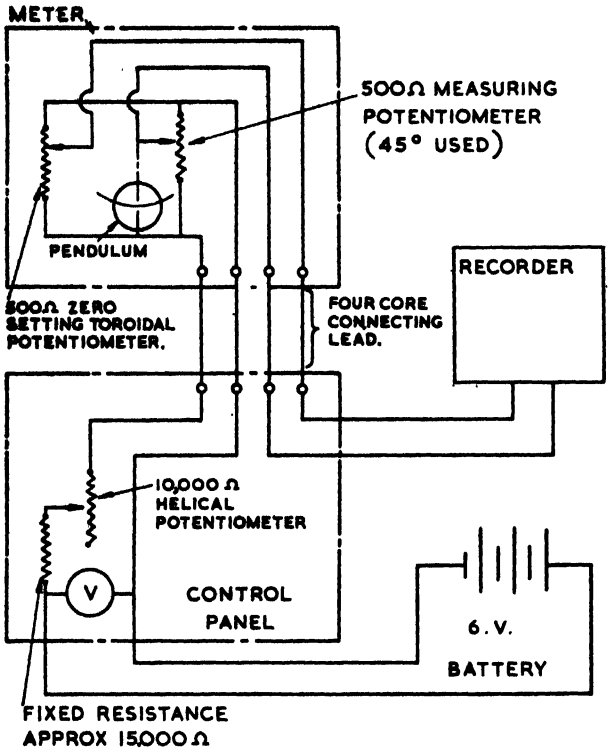


Fig. 9. Declination meter electrical system.

The accuracy of the meter in calibration checks is well within ± ·25° although in practice with severe warp vibration present, interpretation of the records to better than ± ·5° would not be claimed.

A typical recording is shown in Fig. 8.

4·4 Warp heel meter

It is noted that in all cases where the trawl is properly set, the heel if any is such that the outer warp is high and therefore it is not necessary to have a meter reading both sides of zero. This meter is therefore exactly the same as the declination meter described in paragraph 4·3 but is mounted transversely on the divergence meter as shown in Fig. 6.

It is noted that as the heel angle is of secondary importance, the heel meter is in effect a spare for the declination meter.

4·5 Ship's speed log

A Kelvin Hughes Standard Direct Reading Current Meter (range 0 to 6 knots) has been adapted for this purpose. The meter is towed off the ship's side at a distance of about 15 ft and a depth of about 20 ft and the electrical lead run to the indicator unit located adjacent to the main control panel and recorder rack. A modification to the standard indicator unit enables the signal to be taken to one of the recorders for continuous recording. The calibration, made in our own water test tank, is of log scale type and a setting potentiometer added to the indicator unit is set so that the output to the recorder at 6 knots is 12 mv.

The meter and indicator unit is shown in Fig. 10.

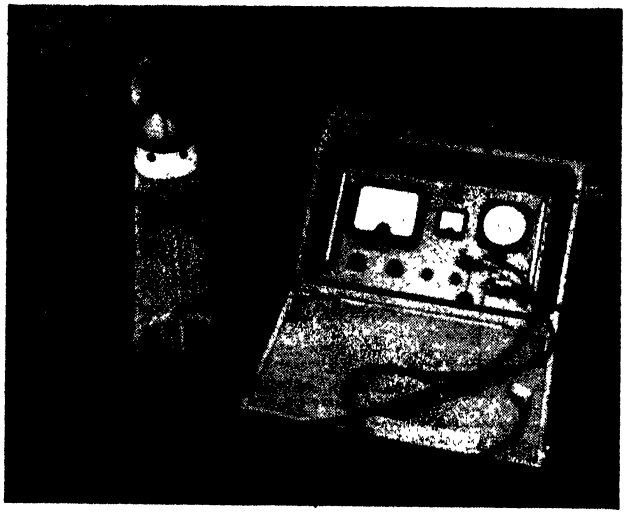


Fig. 10. Kelvin Hughes Direct Reading Meter used for ship's speed recording.

4·6 Control panel and recorders

The individual control circuits and recorders referred to in paragraph 4·1 to 4·5 have in practice been incorporated in a single control panel mounted in a rack with six recorders. This is shown in Fig. 11. Wander leads with Jack plug connectors are used for the recorder signals and hence any one of the six recorders can be used with any one of the meters and in the event of a recorder failure, the least important meter can be cut out with only a minimum of loss of recording of the more important data.

Incorporated in the panel is a recorder test point whereby a known signal of say 5 mv can be fed into the recorders to check that they are functioning correctly.

As previously mentioned in paragraph 3·1, the recorders are Leeds and Northrup Type H model S strip chart 0 to 12 mv. The power supply required for these is 240 V AC and as it is necessary that a zero potential neutral wire system is used, an isolating transformer is included in the rack to suit the usual ship's supply system. Power supply for the meters is from a nominal 6 V 90 amp hour accumulator mounted on the rack. The high capacity is provided so that even with all the meters in use at the same time, the voltage change in the course of a haul is completely insignificant. The setting potentiometers on the panel are such that a voltage range of approximately 5·8 to 6·3 V can be covered and hence it is usually unnecessary to require a recharge of the accumulator during the course of a three weeks' test cruise.

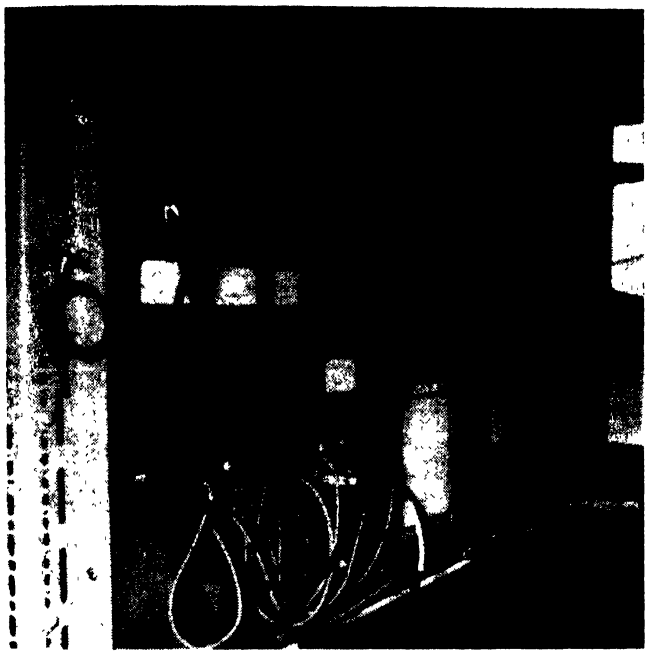


Fig. 11. Control panel and recorder rack.

5. UNDERWATER INSTRUMENTS

5·1 Pressure strength factors

As stated in paragraph 3·2, all the underwater instruments were designed for operation at all depths down to 300 fathoms and the strength of the casings of the instruments was based on the following design and test load factors and pressures:

Static head pressure at 300 fm	800 lb/in²
Design ultimate factor 2·0	pressure 1,600 lb/in²
Proof test factor 1·5	„ 1,200 lb/in²
Water tightness pressure test factor 1·25	„ 1,000 lb/in²

Stress calculations were also made to check that the design ultimate and proof factors were achieved with the pressure loading in combination with other appropriate loading, eg warp tension loading in the case of the warp load cells. In addition, particular attention was paid to the general robustness of the instruments to withstand, again in combination with the pressure loading, the hard knocking about to be expected with the trawl in use on rough ground. In consequence of this general robustness, together with practical engineering aspects, some of the instruments have pressure strengths in excess of the design ultimate quoted above. One example of this is the larger size load cell which has been by accident tested to 2,500 lb/in² without damage, distortion, or leakage occurring.

5·2 Warp load cells

These cells of a completely self-contained recording type are designed to be inserted in cables by means of shackles.

Cells with three differing load ranges are in use:

(a) recording up to 12½ tons load
(b) „ „ 5 tons load
(c) „ „ 3½ tons load

Except that bourdon tubes of different stiffnesses are fitted, cells (a) and (b) are identical to each other. Cell (c) is of the same basic design as (a) but much smaller in overall size and weight.

To provide general robustness, allow for wear and tear, and to ensure that structural failure did not occur prior to a warp breakage, design ultimate and proof or yield factors of 2·0 and 1·5 respectively on the breaking strength of the warps was used for the design of the cells. For cells (a) a warp size of 3½-inch circumference was assumed with a breaking load of 26 tons, this including an efficiency factor of ·8 on the nominal strength of the wire of 32·5 tons to allow for the reduction in strength at the splice.

Thus

Design ultimate load = 26 × 2 = 52 tons
Design proof load = 26 × 1·5 = 39 tons

Load cells (c) were designed for use in the lighter headline and legs and a cable breaking load of 8 tons was assumed giving:

Design ultimate load = 8 × 2 = 16 tons
Design proof load = 8 × 1·5 = 12 tons

5·2·1 Cells (a) and (b)

Fig. 12 shows an opened cell, and Fig. 13 illustrates cells fitted to the trawl prior to shooting.

Fig. 14 shows a longitudinal section through the cell from which it is seen that it works on the hydrostatic principle, with the applied load giving a proportional pressure in an oil filled cylinder, the pressure being measured by a bourdon tube and recorded.

An oil filled thin walled synthetic rubber bag is housed in a cylinder and fixed to the underside of a piston on the top of which are mounted the bourdon tube and drum

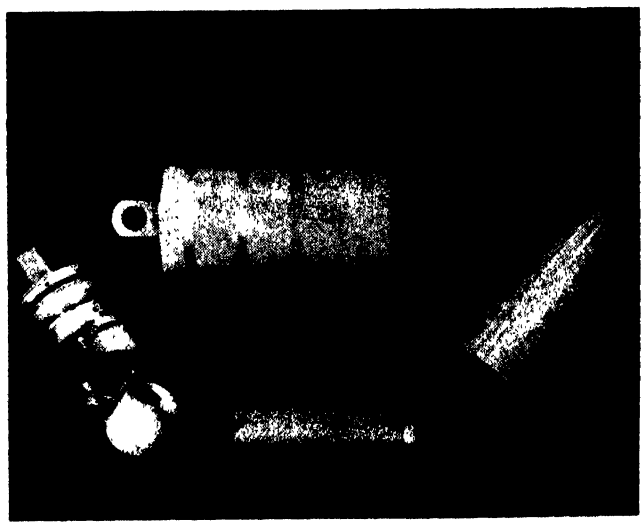


Fig. 12. 12½-ton underwater load cell.

Fig. 13. Underwater load cells fitted in trawl wires prior to shooting.

clock and the battery for the stylus heating power. The oil connection from the bag to the bourdon tube is through one of the fixing studs of the bag to the piston. The piston rod passes through the bag and the cylinder end to form the eye for one of the attachment shackles. Water-tightness at the piston rod entry through the cylinder end is achieved by a diaphragm seal, the seal clamping ring on the cylinder end also being used as the stop for the torque pin which prevents rotation of the piston in the cylinder under the action of the twisting loads in the warp.

The pressure-tight case, which at its other end has an eye for the shackle attachment, is screwed onto the cylinder and locked by two screws. It is this joint which is broken for access to the recording charts, etc. each time the cell is used. This joint is sealed with a synthetic O-ring seal. Fitted to the top of the piston by four screws is a removable extension tube which terminates in a flat-ended spigot of the same diameter as the piston rod. The spigot locates in a bearing in the end of the case and the flat end butts against a synthetic rubber diaphragm, the outside of which is open to the water. Thus both the piston and cylinder have balanced longitudinal loads due to the static head pressure of the water and the recorded cable loads are completely independent of depth of water.

The cells are made mainly of mild steel with a few highly stressed parts, such as the piston rod, of high tensile alloy steel, and with cleaning and suitable maintenance after each cruise, corrosion has not been a serious problem. A ¼-inch thick rubber cover is fitted around the cell to act as a shock absorber and protect the clock and bourdon tube movement.

The length between the shackle pin holes is 16·5 in and the outside diameter of the case is 5·6 in.

The cells weigh 71 lb in air and 53 lb in water.

The effective piston area is approximately 10 in² and thus the oil pressure at the maximum recording load of 12½ tons is 2,830 lb/in².

The bourdon tube, of stainless steel, is of the normal circular type with a simple lever movement. The stylus end is formed by a loop of nickel-chrome resistance wire and the heating power is from a standard rechargeable lead acid dry accumulator which will give approximately 3½ hrs continuous recording.

Starting the clock and switching on the stylus heating, is effected immediately prior to shooting by inserting a screw in the meter case which acts on a simple combination switch.

The spring driven drum clock has a chart of heat-sensitive paper of 2·5 inch effective width and 10 inch length which with a drum speed of 1 revolution per 200 minutes gives a paper speed of ·05 inch/min. Note that this is referred to in subsequent paragraphs as the "standard" drum clock. The load scale is 5 tons/inch for cell (a) and 2 tons/inch for cell (b). These load and time scales give adequate accuracy and discrimination, and correlation of the results from numerous instruments used at the same time has been very good.

Typical recordings are shown in Fig. 15.

A typical static calibration curve, Fig. 16, shows a hysteresis loop of about ± 6 per cent which is mainly

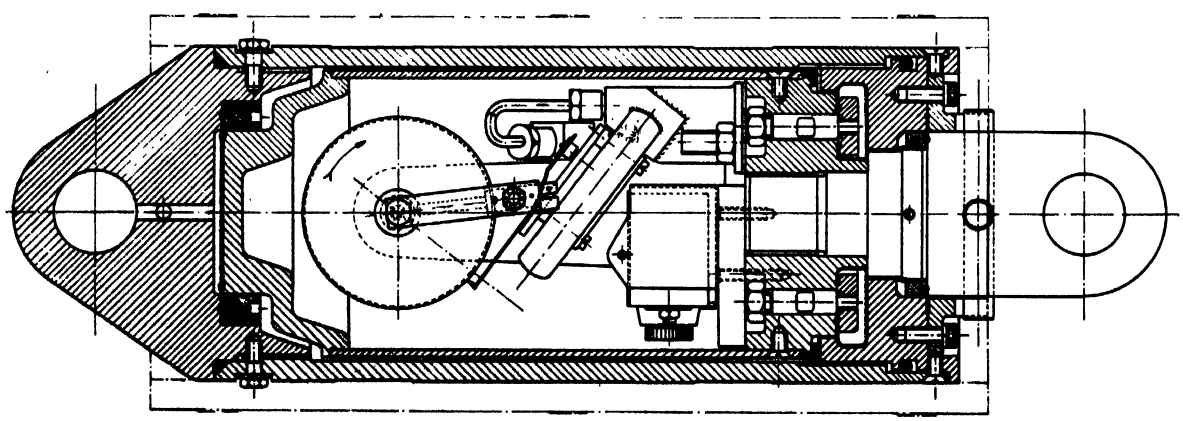


Fig. 14. 12½ and 5-ton load cells.

from the bourdon tube itself. Limited response tests with a superimposed sinusoidal vibrating load for cell (a) showed, at a typical loading of about 3 tons ± ·4 tons, results very close to those for the static loading up to a frequency of about 50 cycles/minute, and at 60 cycles some slight fall-off was noticeable. For cell (b) a similar result was found at a loading of 2·15 ± ·65 tons.

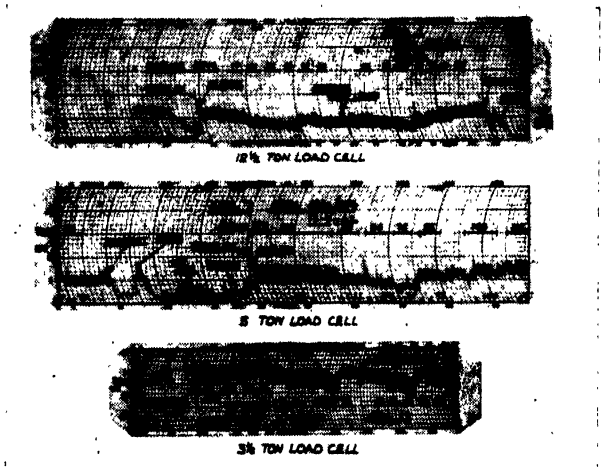
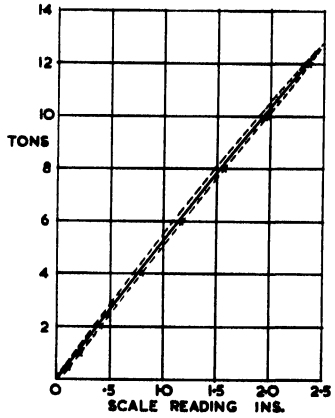


Fig. 15. Typical load cell recordings.

Thus taking the mean calibration line and the mean amplitude of typical recordings the error should be very small but taking into account all the possible variations a general accuracy of less than about ± 4 per cent is not claimed. For general research this has been found to be adequate. It should be noted that for individual high peak loads—such as in shooting loads—the increasing load calibration line should be used.



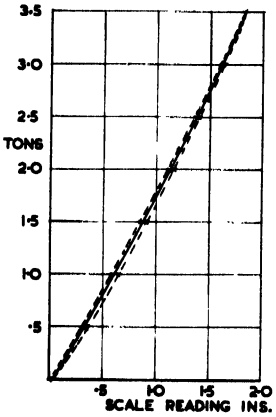


Fig. 16. (Left) 12·5-ton load cell calibration. Typical.
Fig. 17. (Right) 3·5-ton load cell calibration. Typical.

5·2·2 Cells (c)

These cells are in their general operation and construction the same as cells (a) and (b).

The effective piston area is approximately 5·9 in² and thus the oil pressure at the maximum recording load of 3½ tons is 1,330 lb/in².

A smaller size drum clock is fitted and this has a chart of effective width of 1·75 in and length 7 in which with a drum speed of 1 revolution/200 min gives a paper speed of ·035 in/min. The load scale is 2 tons/in.

A typical recording is shown in Fig. 15 and a typical calibration curve in Fig. 17. The accuracy is of the same order as the larger cells (a) and (b).

The length between the shackle pins is 14·6 in and the outside diameter of the case is 4·25 in.

The cells weigh 26 lb in air and 21 lb in water.

5·3 Warp declination meter

This meter, shown in Fig. 18, has a simple pendulum, the pivot shaft of which is carried in two miniature low friction ball bearings, with damping by an air cylinder and piston made from a standard glass hypodermic syringe. A small needle valve is fitted to the cylinder end for damping adjustment. This damper has proved to be very cheap and effective. A stylus fitted on the end of the pendulum shaft traces its movements onto a standard drum clock chart.

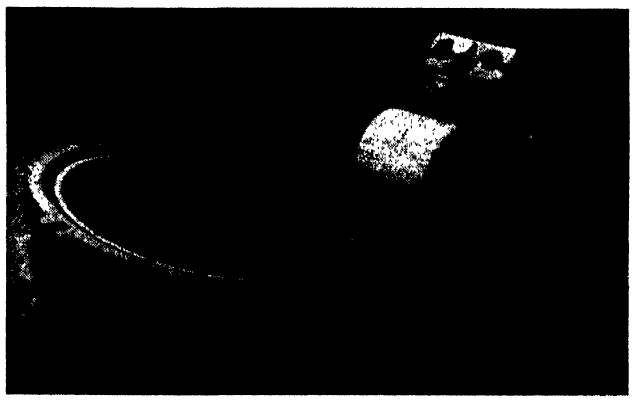


Fig. 18. Warp declination meter.

The instrument, including the stowage of the battery for the stylus heating, is assembled on a base plate, which is bolted into a spherical pressure case. On the top of the case two projecting lugs, with split bearings, form a hinge with the warp as the hinge pin, thus the whole instrument hangs as a pendulum below the warp which can rotate without affecting the instrument but the instrument is constrained to take up the declination attitude of the warp and this is recorded.

The zero angle datum is the centre-line of the chart, the stylus being carefully set, after assembly of the instrument in the case, with the warp at zero angle.

The recorded angle is simply determined by

$$\text{Angle} = \text{Sin}^{-1}\frac{\text{ordinate from centre line of chart}}{\text{length of stylus}} = \text{Sin}^{-1}\frac{\text{ordinate}''}{2{\cdot}75''}$$

The maximum angles which can be recorded are ± 27°

It is obvious, however, that the water flow past the instrument mounted in the manner described above

would cause instability and rotation of the instrument around the warp. To obviate this, a completely independent spherical shell is fitted on the warp around the instrument case. This shell is water flooded and thus provides dead water around the instrument and allows it to hang steady and stable. Fig. 19 shows a diagrammatic arrangement of the assembly and Fig. 20 the meter fitted to the fore warp ready for shooting. This has proved very satisfactory and good recordings have been obtained, a typical one being shown in Fig. 21.

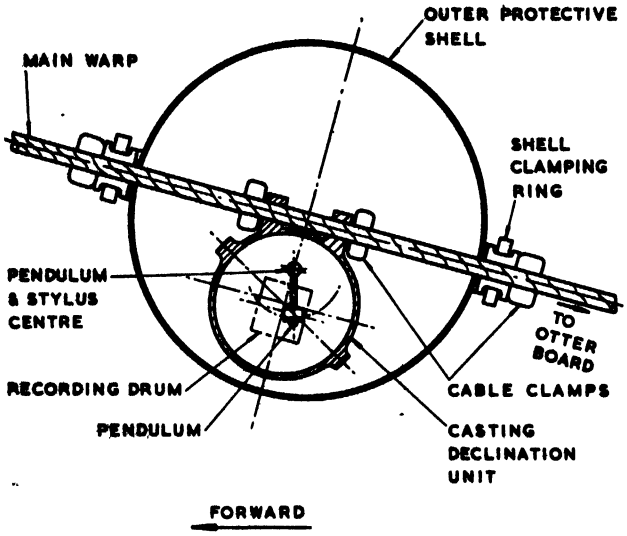


Fig. 19. Warp declination meter.

The spherical instrument case, 8¾-inch outside diameter, is made of two corrosion resistant aluminium alloy castings, bolted together by three swing bolts on a diametric joint incorporating an O-ring seal.

No corrosion or leakage problems have arisen.

The spherical shell 22-inch diameter and split into two halves on the diameter containing the warp, is made of 10 swg corrosion resistant aluminium alloy. The two halves are held together and onto the warp by only two clamps around the bearings on the warp and the instrument and shell are located by four stops clamped on the warp.

The weight of the meter excluding the warp stops and shell is 19 lb in air and 3 lb approximately in water.

5·4 Otter board angle of heel meter

The meter itself is exactly the same as the warp declination meter described in paragraph 5·3. It is also assembled in a cast aluminium alloy spherical case of the same size as that of the warp meter but has four lugs, in the shape of a cruciform, on each half casting for a four stud attachment to the otter board. The cruciform arrangement of the lugs is so that the meter can be turned through 90° and used as a pitch meter. Fig. 22 shows the meter mounted on an otter board, and Fig. 21 a typical recording.

The meter weighs 18 lb in air and 2 lb approximately in water.

5·5 Otter board angle of attack meter

This instrument was not designed by Westland Aircraft but was "bought-out" as a fully developed working meter. It was designed on the principle that a rod hinged on the board at one end on both the vertical and horizontal axis and the other end trailing on the ground would take up the direction of the otter board over the ground and thus the rotation around the vertical axis with respect to the board would give the angle of attack and could be recorded. The instrument consists of a vertical shaft operating, through a gear, a stylus

Fig. 20. Warp declination meter at board ready for shooting.

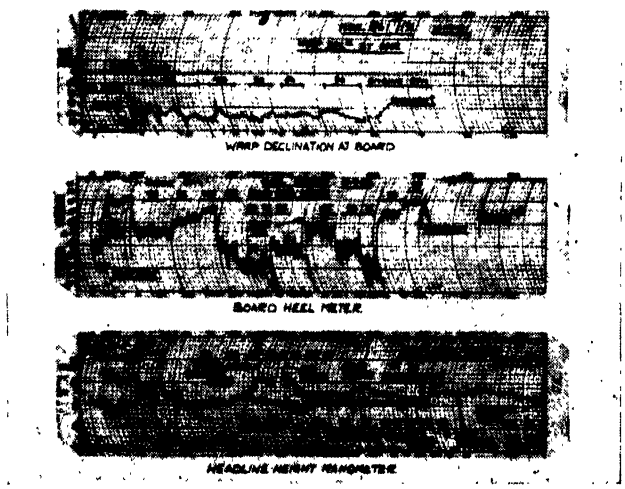


Fig. 21. Typical recordings.

which records on a circular chart driven by a spring clock. The instrument is housed in a flat cylindrical phosphor bronze case, with the shaft entry sealed with rubber "O" rings and the case cover fixed by eight studs and sealed with a square section seal ring.

The meter weighs 45 lb in air and 34 lb in water.

In practice satisfactory records could not be obtained, as on a good smooth ground the impossibly large angle of 60°, the limiting stop angle of the instrument, was indicated, whilst on rougher ground random fluctuating angles of large amplitude intermittent with the limiting stop angle were indicated. In addition repeated failures either by complete breaking or bending of the shaft occurred.

A theoretical study of the otter board motions and of the meter operation indicated that both the unsatisfactory records and the shaft failures were probably from the same cause. Normally the board is heeled outwards 10-20° and in this condition the weight of the trailing rod taken at the board end biased the reading to a much higher apparent angle of attack and this combined with the oscillatory heeling motion of the board induced by the varying ground side forces, particularly on rough ground, gave the random fluctuating angles. Although attempts were made to use a trailing wire with floats to act as a drogue these were not successful for various reasons and it was decided that this method of measuring the angle of attack of the boards should be abandoned.

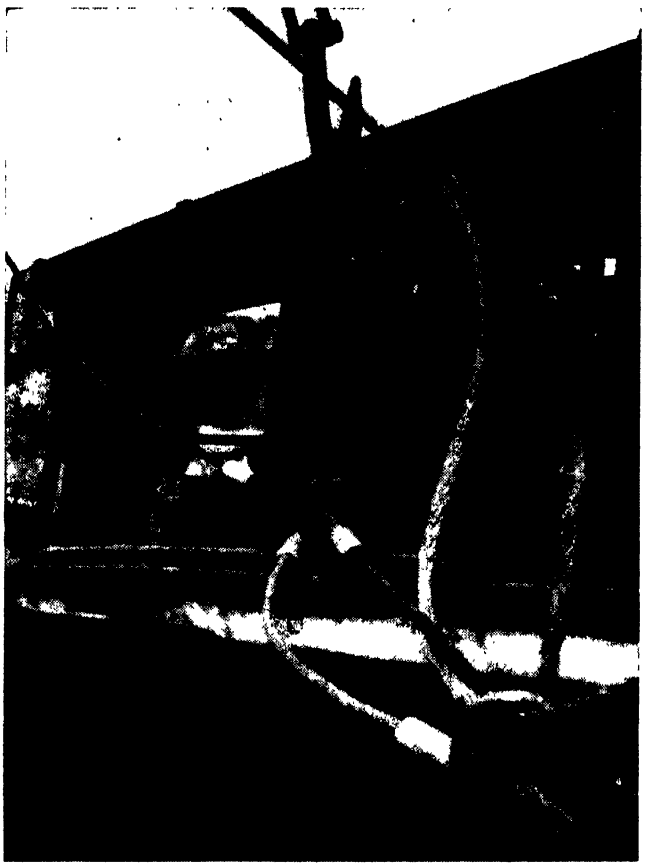


Fig. 22. Otter board heel, pitch and angle of attack meters fitted to board.

However, it was decided to modify the meter and use it to record the board angle of attack relative to the bridles, and thus from the angle of the bridal relative to the direction of motion found by spread measurements, etc. the true angle of attack of the boards could be deduced. This was achieved by attaching the upper backstrop to the board via a vertical shaft which was caused to rotate with any change of angle of the backstrop to the board and this rotation was transmitted to the meter by a system of levers and rods. Fig. 22 shows the meter mounted on the board.

By this means the board angles of attack have been determined to a probable accuracy of ± 3°.

5·6 Board pitch meter

This instrument was not designed by Westland Aircraft but "bought-out" as a developed working instrument.

The instrument, shown, mounted on the board, in Fig. 22, consists of a pendulum on pivot bearings carrying a pin stylus recording on a circular wax faced paper chart. The chart is on a disc driven by a spring operated clock at a speed of 1 revolution/4 hrs, and of course the paper speed varies with the amplitude of the angle.

When first used the results were unsatisfactory as the only damping of the pendulum was by adjustment of the stylus pressure, which proved difficult to set just right; either the pendulum thrashed about at random or the stylus "dug in" and tore the surface of the paper.

An air cylinder and piston damper similar to that described in paragraph 5·3 was fitted and this improved the performance considerably and satisfactory recordings were obtained.

The instrument is housed in a flat cylindrical phosphor bronze case, and is attached to the board by four studs and with a special bracket can be mounted to measure the heel angles of the board.

The meter weighs 35 lb in air and 26 lb in water.

The very high weight of this instrument as compared with the heel or pitch meter described in paragraph 5·3 is to be noted.

5·7 Electronic spread meters Mk 1A and Mk 2

These electronic instruments were designed by the Electronics Department of Saunders-Roe. As a Structural Engineer, the author limits himself to describing the structural and operational aspects.

5·7·1 Board spread meters (Mk 2)

The functioning of this spread meter depends on basic principles similar to those relating to conventional echo sounders. It consists of two units referred to as the Recorder and Responder unit respectively, these being fixed at the two points between which it is required to measure the distance. On each of these units two piezoelectric transducers are fitted, one transmitting and the other receiving. A signal is transmitted from the Recorder unit to be received by the Responder unit which re-transmits it, at a different frequency, back to the Recorder unit where it is recorded on "teledeltos" paper

together with the original transmitted signal. The recorder itself is a standard instrument using standard echo sounder chart paper marked in fathoms. The electronic units are housed in identical cases made up of aluminium alloy thick walled tubes with bolted on end covers. One end cover is semi-permanent and has built in an on-off switch whilst the other is removable for normal access to the units. Synthetic rubber O-rings are used for sealing to ensure water-tightness. The transducers are mounted in the wall of the tube and once again O-ring seals are used.

Direct mounting on the boards proved to be unsatisfactory because of ground interference with the signal and the changing heeling angles causing misalignment of the units. A satisfactory method of operation was found to be by towing the units well clear of the ground and for this purpose a conical tail cone of the type developed by Messrs. Kelvin Hughes for the Current Meters was made and fitted to each unit. The unit is pivoted on a horizontal axis at its centre of gravity to extension arms of a towing hanger or frame which lies above the unit. The units complete with tail cones and hangers are shown in Fig. 23.

Fig. 23. Otter board electronic spread meters (Mk 2).

The units are towed via the hangers, one from each warp, at a distance of 20 to 25 fathoms forward of the otter boards by cables, approximately 12 ft long, with freely rotating attachments to the warps. A clamp stop on the warp prevents the meter sliding down towards the board. A wire about 18 ft long is attached to the aft end of the frame and at the other end deep-sea floats are fixed to act both as a drogue to give towing stability and also to lift the units clear of the warps. The floats have a buoyancy of about 60 lb so that if the unit breaks away from the warp it will be floated to the surface, the weight of the unit in water being about 45 lb (90 lb in air).

The arrangement is shown diagrammatically in Fig. 24.

It is to be noted that care must be taken to see that the units are attached to the appropriate warps with the transducers facing each other.

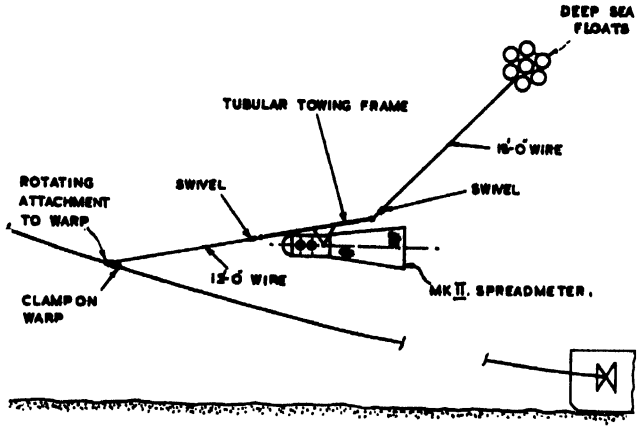


Fig. 24. Towing arrangement of Mk 2 Spread Meter.

5·7·2 Netmouth spread meter (Mk 1A)

In this spread meter a single unit is used with two remote transducers—one transmitting, the other receiving —connected to the unit by electric cables.

The unit is shown in Fig. 25.

Fig. 25. Net mouth. Electronic Spread Meter Mk 1A.

The electronic and recording systems are almost identical to those of the Mk 2 unit of paragraph 5·7·1 and are housed in a spherical case, 13 in outside diameter, of cast aluminium alloy, made in two halves bolted together with an O-ring seal in the joint. The joint bolts also fix a square mounting plate to the case and this plate is attached to the headline at about the quarter point by two shackles. A number of deep-sea floats are attached to the opposite edge of the plate to give buoyancy to the meter to lift it clear of the headline and float it to the surface if it breaks away from the trawl.

The meter weighs 14 lb in water and 77 lb in air.

The electric cables, one to each wing end, are lashed to the headline and the transducers are fixed to wooden

boards with wedge shaped tails, towed from the wing end on short lines. Tail lines with three deep-sea floats attached act as drogues and lift the transducers clear of the net.

5·8 Headline height manometer

This meter measuring the headline height relative to the groundrope is a differential manometer fully enclosed in a pressure-resistant case so that it is completely surrounded by air at ambient pressure, and thus the instrument operation and recording is independent of the depth of water in which the trawl is being used. A diagrammatic arrangement is shown in Fig. 26.

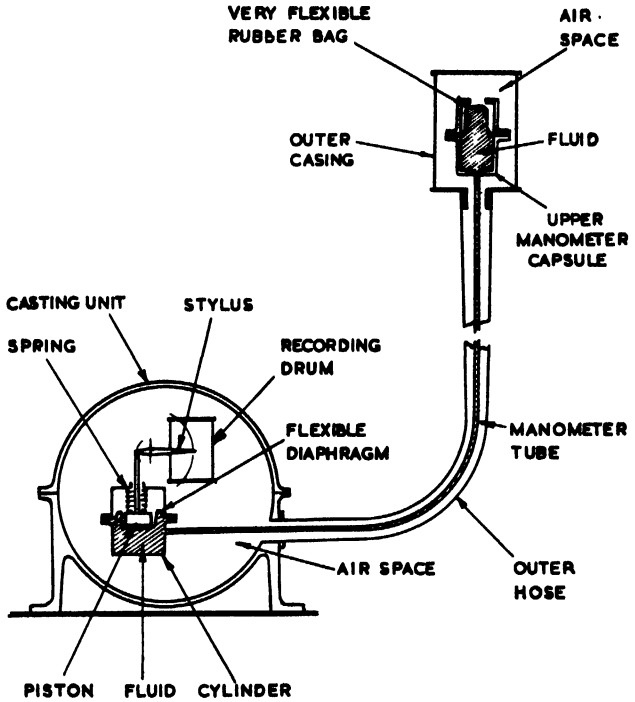


Fig. 26. Diagrammatic arrangement of manometer.

Fig. 27 shows the manometer with the recorder case open.

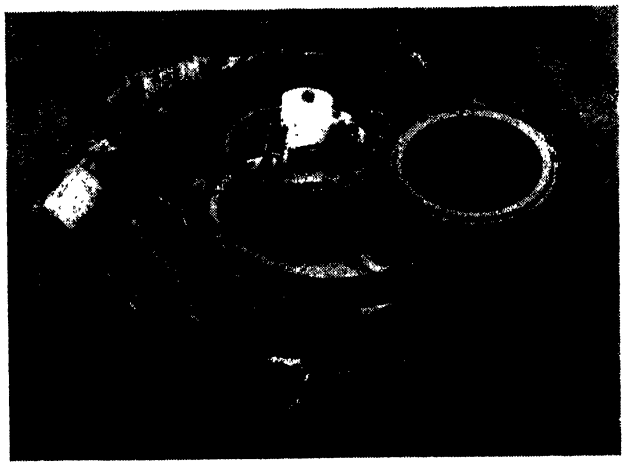


Fig. 27. Headline height manometer.

The pressure measuring unit consists of a cylinder filled with fluid with a Bellofram rolling seal to transmit the fluid pressure to a piston, whose movement, proportional to the pressure, is controlled by a helical compression spring. The piston is connected by a simple rod and lever system to a heated stylus recording the piston movement on a "standard" clock drum chart. The cylinder is connected by a nylon tube of 4·3 mm O/D × 2·9 mm (·17 in × ·115 in) bore to a head capsule which consists of an open ended cylinder enclosing a very thin and very flexible rubber bag. The system is filled with a low viscosity silicone fluid. The pressure recording unit is housed in a spherical case of cast aluminium alloy of the same diameter, thickness, etc. as for the declination meter of paragraph 5·3 but on the lower half an integral skirt is provided for the attachment to a base plate. The spherical case is connected to the small case containing the head capsule by a hose which contains the nylon tube. The hose is a standard braided, rubber, high pressure hydraulic hose with a steel wire helically wound flexible conduit inserted through the bore, to give rigidity of the hose under the external water pressure from the static head. The bore of the conduit is ·25 inch and thus gives an annular air space around the nylon tube and the outside diameter of the hose is approximately ·8 inch. The hose is jointed with standard re-usable connectors.

Two channels are provided in the instrument although of course one can easily be removed if required. A version with four channels has been used but handling on the trawl proved difficult and overlapping of the traces caused difficulties in interpretation of the records and hence two-channel instruments are to be recommended.

To prevent stretching of the hose, which would cause damage to the nylon tube, it is marled along a ¾-inch circumference flexible wire cable the ends of which are secured to the recorder and head cases respectively.

The installation on the trawl is shown diagrammatically in Fig. 28.

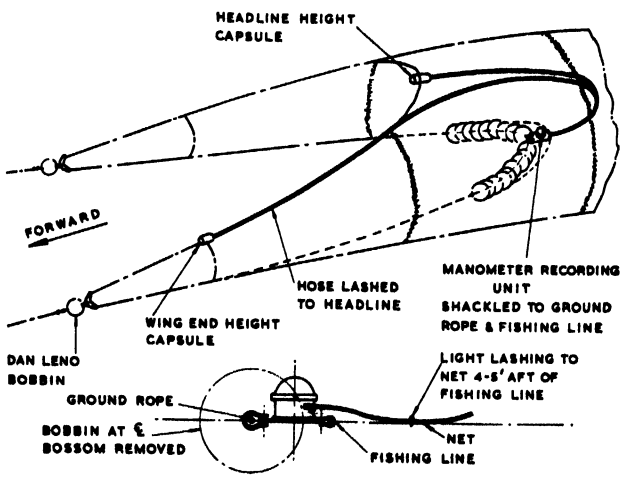


Fig. 28. Headline height manometer diagrammatic arrangement in trawl.

The head capsules are lashed to the headline, generally at the centreline and the wing end, with the wing end capsule hose lashed along the inside of the headline to the quarter point. The hoses then flow in a large bight inside the net to the recording case on the centre of the groundrope. The recording case base plate is fixed to the groundrope by two large bow shackles and by a further two shackles to the fishingline. This method of operation has proved to be very satisfactory and very few difficulties have arisen even with hoses of up to 80 ft in length.

The height recording range of the instruments in use is 0 to 25 ft and this is essentially for net openings of 10 to 20 ft but the range can easily be changed by fitting springs of different stiffnesses.

A typical static calibration curve, Fig. 29 shows a hysteresis loop of about ± 9 inch.

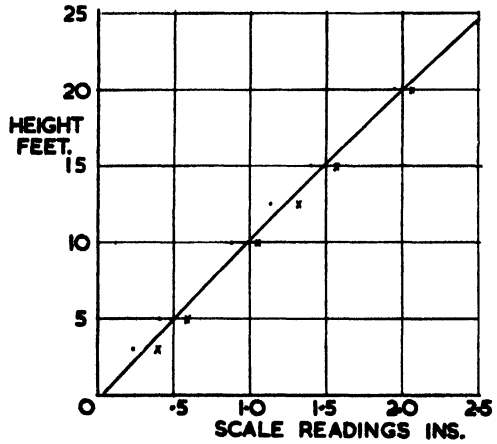


Fig. 29. Manometer calibration. Typical.

In practice continuous oscillations of the trawl, particularly of the groundrope occur, and using the mean calibration curve and the mean indicated ordinate, is considered to give the headline height with an accuracy of within ± 6 in. It is noted that the datum of the instrument is 6 in above the base plate and this 6 in plus the height of the groundrope must be added to the indicated height to obtain the true headline height above the ground.

A typical record is shown in Fig. 21.

The weight of the complete meter is broken down as below :

Case, recorder and mounting plate	28 lb in air, 8 lb in water
Hose, 50 ft length excluding wire	28 lb in air, 18 lb in water
Head capsule and case	5 lb in air, 3 lb in water

5·9 Trawl speed meters

To make an accurate analysis of a trawl test, it is necessary to know the trawl speed through the water as this is not necessarily (due to tides and currents) the same as the ship's speed and it is also desirable to know the pressure or speed of the water in the trawl mouth. A Kelvin Hughes Current Meter has been adapted for use in determining these speeds.

The standard underwater meter has been modified so that the electrical impulses from the cam contacts are at a frequency of about 35/min at 5 knots, the frequency being proportional to the speed. The electrical lead is taken to a spherical cast aluminium case containing the recording unit and power supplies. The power supply consists of four 4½ V dry flat type torch batteries A spring clock drives a drum with a plain heat sensitive chart and also rotates a lead screw which moves its cross head, carrying a heated stylus across the chart and thus a helical trace is recorded. The electrical impulses operate, through a relay and condenser circuit, a solenoid which moves the lead screw, and hence the stylus endways about ·03 in and produces a series of blips on the helical trace. The number of blips per unit of time or from the paper speed, the number per unit of length of trace is proportional to the water speed and can be counted. This is a very laborious process and in general only a few short periods of a few minutes each in a full haul are analysed. The drum timing is 5 minutes/revolution and the paper speed approximately 2 in/min and thus at 5 knots there are about 17 blips/in of trace.

The recorder case is of cast aluminium of the same dimensions as that of the declination meter of paragraph 5·3. An integral lug on the centre of each half of the case is used for a shackle attachment. A general view is shown in Fig. 30.

Fig. 30. Trawl speed meter and recorder.

For the general trawl speed the meter and recorder are assembled as shown in Fig. 31 and attached to the aft warp about 25 fathoms forward of the otter board and this method has been found simple and effective in operation. For the trawl mouth speed the recorder case is attached directly to the head line and the meter, with a ballast weight hung below it, is streamed on an appropriate length of wire. Only limited tests for the mouth speed have been made to date and, as can be imagined, difficulties in preventing damage to the meter arise in all but good weather conditions.

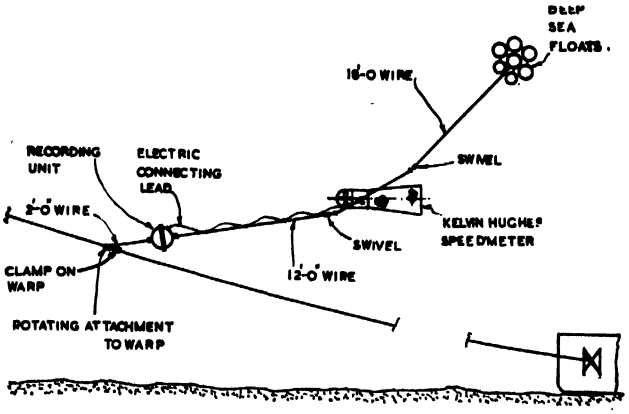


Fig. 31. Towing arrangement of trawl speed meter.

5·10 Net twine load cells

In the past, numerous attempts have been made to determine the loads in the twines of the net and as far as can be ascertained these have all been on the principle of replacing the twines by wires of known strength and seeing which ones break. This system in fact only indicates that a certain load has been exceeded.

With the load cells used in the present project a new approach has been made to determine the maximum load occurring in any selected twine during the course of a haul.

The principle of the design is based on the well-proven Brinell Hardness test, a hardened steel ball being used to give an indentation in a relatively soft metal plate. The depth of the indentation, and hence the diameter which can easily be measured, given in a uniform plate by a given diameter of steel ball, has a regular relationship with the load applied to impress the ball in the plate.

The load cell is shown in Fig. 32 and consists of two phosphor bronze U fittings—one sliding inside the other and held together by a light spring—one having a stainless steel ball fixed to the inside of the base and the other having a recess to hold an indentation disc.

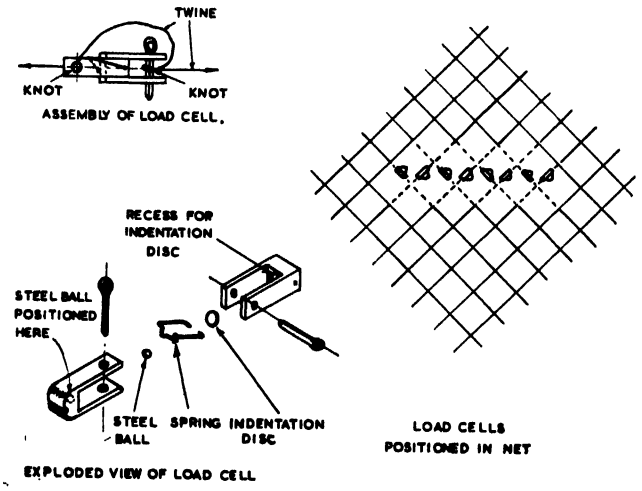


Fig. 32. Arrangement of net twine load cells.

The size of ball and indentation material can be selected to suit the load range. On the ones in use a $^{3}/_{32}$-in diameter ball with aluminium alloy plates of the order of 140 Brinell Hardness give a load range of 10-300 lb.

A measuring micrometer microscope is used to obtain the impression diameter. In the development stage, tests were made with the load maintained for various periods from 5 sec to 2 hrs and also ones when the load was varied up and down within the maximum during a period of 1 hr and the results all fell within the normal scatter range.

Calibration tests are carried out on each batch of discs and show an accuracy of better than 5 per cent but in practice on the trawl it is probable that a somewhat lower degree of accuracy is obtained although considerably better results can be claimed as compared with those from methods used hitherto.

In practice it is desirable, in fact necessary, to use a number of cells, say not less than 12, in a row across the net in adjacent twines. The simplest and quickest way to insert the cells in the net is shown in Fig. 32. The cells are knotted onto a single length of twine, the distance between the centres of the cells being equal to the mesh-bar length (plus allowance for the knot). Three rows of the net are cut out over the required length and then re-braided using the twine containing the cells for the centre row.

The length of the cells is only 1 in between the pins and thus can be fitted fairly easily in about 4-in mesh netting.

6. FULL-SCALE TRAWL TESTS

In carrying out full-scale trials, the number and type of instruments used in any given haul depends on the particular aspects of the trawl behaviour or performances being studied. In general, however, the deck type instruments are used and complete records made for all hauls together with load cells, in the warps immediately forward of the boards and in the backstrops, and the headline height manometer. From this limited instrumentation a very good indication of the trawl behaviour can be obtained.

In many hauls the whole range of instruments with up to ten load cells inserted in the cables are used, and with these the trawl must be about the most expensive of its type ever put over the side.

Many of the instruments, such as the underwater load cells, can be used in almost any weather but it has been found that, in general, force 5 is the limiting weather for most research work. This is because of the difficulty in operating the gear with instruments and the possibility of instrument damage or loss and injury to personnel and also, with worsening weather, the oscillation amplitudes become so large that the records become unsatisfactory and correlation of the results from the various instruments is virtually impossible.

Considering the very severe conditions under which the instruments have to work, the reliability and serviceability of the instruments has been found, in general, to be very good although, it must be admitted, some do

require improvement in this respect. All the deck instruments give almost 100 per cent reliability, occasional trouble being given, mainly due to vibration, by the divergence meter potentiometer, replacement of which can be made without difficulty on board the ship. In the underwater mechanical instruments the troubles are practically wholly confined to failures of the clocks, styluses and the wiring all of which can be repaired or replaced on board the ship. Very little trouble from water leakage has been experienced. In about one in 10 to 15 hauls the manometer hoses get tangled around the groundrope and are broken, causing flooding of the whole instrument. Repairs can be carried out on board by washing out with fresh water and drying and fitting a new clock and hoses. In recent cruises with up to 150 individual records per cruise the reliability of the load cells has been 95 per cent and the other instruments are only slightly lower.

The speed meters have given trouble mainly through water leakage and consequent short circuiting of the joints of the electric cables to the meters and recorder cases and similar problems have arisen on the spread meters but these have now been overcome and it is thought that a high degree of reliability will be obtained in future on all these instruments.

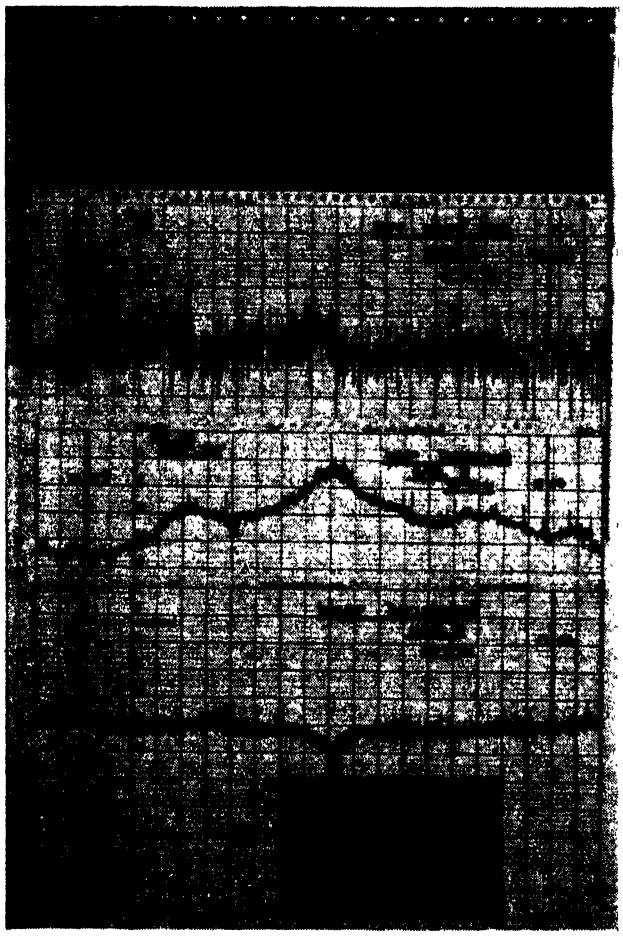


Fig. 33. Illustration of correlated recordings.

As an indication of the degree of correlation of results which can be obtained from various instruments and also to show the interdependence of the various paramenters Fig. 33 shows portions of the echo sounder depth, the warp load, divergence, declination and manometer records of one haul. The depth records shows a valley, over which the trawl took about 20 min to cross, and the other records show the corresponding behaviour of the trawl very clearly. As to be expected, as the trawl passed down the valley side, the trawl mouth closed, the declination of the warps increased, the warp load decreased, and the headline height increased, and then as it climbed the other side the reverse happened and the trawl regained its normal configuration when it had passed completely over the valley.

It is interesting to note that analysis of the trawl in the two widely differing configurations, i.e. normal and at the bottom of the valley, by the methods and equation

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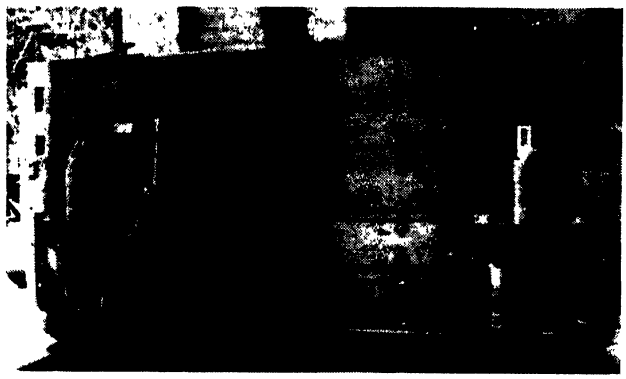
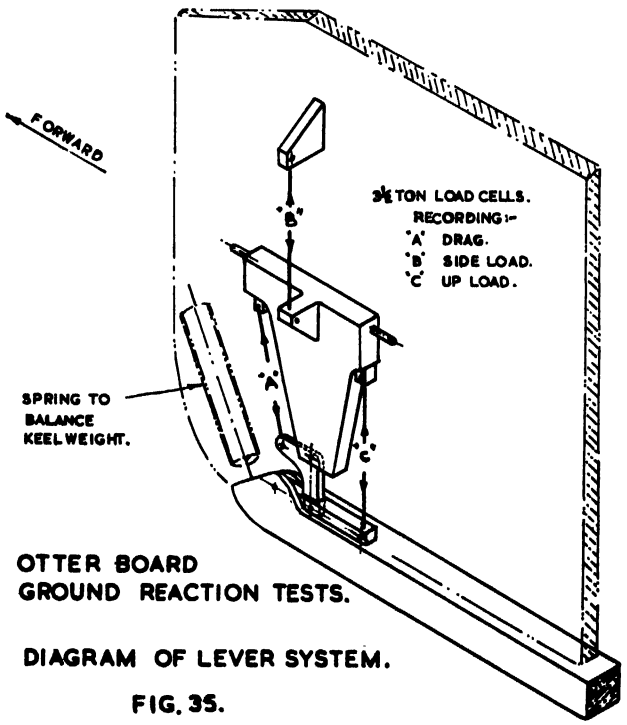


Fig. 34. Otter Boards instrumented to determine ground reactions.



Some Japanese Instruments for Measuring Fishing Gear Performance

by
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and
Kenji Ishii

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Abstract

Measurements and observations of the main characteristics of full-scale fishing gear in operation under actual fishing conditions are indispensable for rational studies aiming at development of new, or improvement of existing, fishing gear and methods. Since 1957, the authors have been engaged in designing measuring instruments adapted for this purpose. A short description of the principle, construction and performance is given of the following measuring instruments presently used in Japan: recording net height meter, recording depth meter, combined recording depth and temperature meter, recording current meter, recording underwater dynamometer, dynamometer for trawl warps, recording groundrope indicator, low-speed log for trawlers, recording depth meter for gillnets. All these instruments have a surprisingly high grade of accuracy and are, at the same time, extremely small and light and thus very handy. Their main characteristics are given in Table I.

Quelques instruments Japonais pour mesurer le comportement des engin de pêche

Résumé

Les measures et observations des principales caractéristiques des engins de pêche opérant actuellement sont nécessaires pour conduire rationellement des études visant à perfectionner les engins existants ou en développer de nouveaux. Dans ce but, depuis 1957 les auteurs ont travaillé sur les dessins d'instruments de mesures. Cette communication comprend une courte description des principes de construction et du comportement d'enregistreur de hauteur de corde de dos, enregistreur-sondeur, enregistreur-sondeur et thermomètre combinés, enregistreur de courant, dynamomètre, enregistreur sous-marin, dynamomètre de fune, enregistreur de ligne de fond, loch de chalutage, enregistreur-sondeur pour filets maillants, tous ces instruments étant actuellement utilisés au Japon. Ils sont d'une haute précision et en même temps petits, légers et faciles à manipuler. Les caractéristiques de ces instruments sont données au Tableau I.

Instrumentos Japoneses para medir el rendimiento de los artes de pesca

Extracto

Medir y observar las características principales de los artes de pesca funcionando en condiciones reales son indispensables para efectuar estudios racionales encaminados a preparar nuevos materiales y métodos de pesca o a mejorar los actuales. Desde 1957 los autores proyectan aparatos medidores especialmente para èllo. Se describen

continued from page 512

developed, shows complete balance of forces and this is, of course, what must be so in the trawl,

These results give us confidence in both the instruments and in the theoretical work.

A test arrangement worthy of note is that made to determine the ground loads applied to the boards. The special board is of the same size and very nearly the same weight as the standard board. The keel bar or shoe is attached to the board at only two points through a system of levers and links incorporating five 3½-ton load cells to measure the upward, side and drag ground reaction forces. Fig. 34 shows the door with the covers and guards removed to expose the lever systems. The drag load on the keel bar is transferred to the board and is measured only at the forward end but the vertical and side loads are transferred and measured at both the forward and aft ends of the board, and thus the centres of these loads can be determined. Fig. 35 shows a diagrammatic arrangement of the lever systems at the forward end. The system at the aft end is very similar but the horizontal arm of the bell crank lever and the attached load cell for measuring the drag forces are deleted, leaving the vertical arm as a plain link unable to transfer drag forces. This test arrangement worked very well and some very useful information was obtained.

7. Conclusions

In this paper it has only been possible to present broad descriptions of the various instruments, and many of the finer points in the design, manufacture and operation have had to be omitted.

We claim that we have now full range of instruments, the data from which in full-scale tests of various trawls has proved invaluable in the development of basic theory relating to trawl gear design, and will in future give further data of importance in the confirmation and extensions of the theory.

This paper is published with the permission of the Westland Aircraft Ltd., and of the White Fish Authority and British Trawlers' Federation for whom the work was undertaken. The responsibility for any statement of fact or opinion is, however, solely the author's.

Acknowledgements

The design and development of these instruments has presented many difficult problems, and full acknowledgement for the valuable advice, information and assistance is given to many colleagues in the author's Company, representatives of the White Fish Authority, many persons in the fishing industry, and finally to the Scientific staff of the Fishing Laboratories of Aberdeen and Lowestoft (on whose Research ships *Explorer* and *Ernest Holt* practically all the full-scale testing was carried out), for their additional help in developing the handling techniques.

Footnote

The instruments described in this paper were used in the trawl gear studies reported on in papers by Crewe and Dickson.

sucintamente los principios, construcción y rendimiento de los siguientes aparatos medidores empleados actualmente en el Japón: medidor registrador de la altura de la red; medidor registrador de la profundidad; medidor registrador de la profundidad y la temperatura combinadas; registrador de la corriente; dinamómetro registrador submarino; dinamómetro para los cables de los artes; indicadores registradores de los burlones; correderas lentas para arrastreros; medidores registradores de la profundidad de los artes de enmalle. Es sorprendente la exactitud de todos estos instrumentos que son, a la vez, muy pequeños y ligeros y, por tanto, fáciles de manejar. Sus características principales se dan en el Cuadro I.

IN the authors' opinion, work aiming at the development or improvement of fishing gear has to include the quantitative determination of the main characteristics of the gear and their variations by taking measurements of full-scale fishing gear under actual fishing conditions. Consequently, for such studies a number of suitable measuring instruments is needed which, to a certain extent, have to be newly designed by modifying and adapting existing measuring principles and instruments to the specific purpose. Since 1951, the authors have been active in the development of such instruments for measuring the forces acting on and for observing the behaviour of fishing gear during operation. Here a short description is given of such instruments as presently used in Japan. Their main characteristics are in Table I.

Recording net height meter

This instrument (Fig. 1) is meant for measuring the vertical distances between different parts of fishing gear, such as groundrope and headline (opening height), wing tips, sweeplines, etc. of trawlnets and Danish seines. In principle, it is a recording differential monometer to which two pressure sensing parts are connected, one directly and one by a plastic (vinyl) hose. Thus the difference in depth, i.e. hydrostatic pressure (Fig. 1, I, h_1-h_2), between the two points to which the pressure sensing parts are attached is measured and recorded continually. In the schematic drawing (Fig. 1, I) one pressure sensing part (B), which is attached to a higher point, contains a polyethylene bag (D) on which the water pressure acts. This pressure is transferred to the measuring and recording part (A), which contains the other pressure sensing part, through the plastic hose and acts on one side of a diaphragm (K2). Plastic bag and hose contain air. The measuring and recording part (A), which is fixed to a lower part of the fishing gear, receives with its pressure sensing part the higher hydrostatic pressure according to its greater depth over the diaphragm (K) and this pressure acts on the other side of the diaphragm K_2. In order to avoid extensive deformation of both diaphragms, the room between them is filled with liquid silicone. In this room a set of bellows (C) is installed which measures the pressure difference between the parts A and B. The respective deformation of the bellows is mechanically amplified and transmitted to a pen (H) which records the pressure difference, converted into a metric depth scale, on a clockwork-driven paper recorder (F).

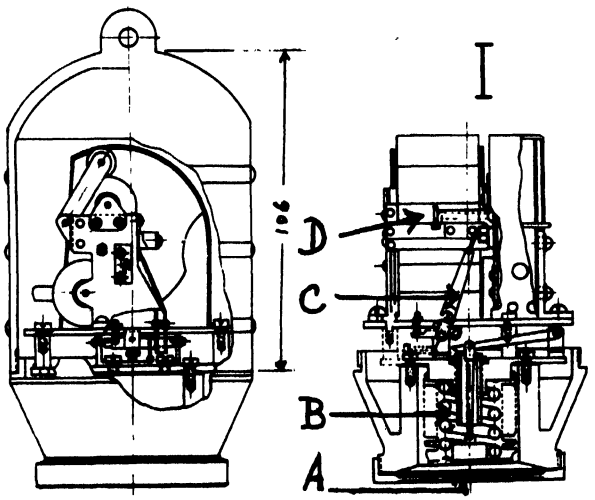
Table I. Main characteristics of the various measuring instruments

	Measuring range	Accuracy, Sensitivity	Maximum operating depth or range	Weight in air Weight in water	Speed of recording paper. Working time
Recording net-height meter	0 to 6 m 0 to 8 m 0 to 14 m 0 to 18 m	± 1 to 2 cm	500 m	3.2 kg 2.5 kg	1 mm/min 24 hrs
Recording depth meter	0 to 180 m 0 to 240 m	± 0.5 to 1.0 m	300 m	32 gr. (in the water)	- do -
Recording depth and temperature meter	A Type. 0 to 150 m -10° C to + 30° C B Type. 40 to 100m 0° C to+40° C	± 0.5 m ± 0.1° C ± 0.05 m ± 0.03° C	200 m	A (2.10 kg (1.15 kg B (3.95 kg (3.10 kg	A (1.5 mm/min (24 hrs B (5.0 mm/min (24 hrs
Recording current meter	0.3 to 2.0 m/sec	± 0.025 m/sec ± 0.01 m/sec	300 m	0.415 kg (in the water)	
Recording underwater dynamometer	0 to 1000 kg 0 to 2000 kg	± 5 kg ± 10 kg	500 m 700 m	3.5 kg 2.1 kg	1 mm/min 24 hrs
Dynamometer for trawl warps	0 to 2700 kg	± 10 kg	10 tons	-	-
Recording groundrope indicator	0 to 100 degrees (for left side and right side footrope)	± 0.5 degrees	150 m	9.7 kg (in the water)	8 mm/min 6 hrs
Tow speed log for trawlers	0.3 to 7.0 m/sec	± 0.05 m/sec	50 m	4.2 kg 3.1 kg	-
Recording depth meter for gillnets	(4 elements) 0 to 3 m 2 to 5 m 4 to 7 m 6.5 to 10 m	± 1 to 2 cm	-	-	1 mm/min 24 hrs

Fig. 1. General structure (I) and photo (II) of the recording net height meter.

Recording depth meter

This instrument (Fig. 2), which is meant for measuring the water depth in which fishing gear, or parts of it, are operating, is actually a simplified version of the recording net height meter described before. It consists of only one pressure sensing part with paper recorder. The pressure is measured by a membrane (Fig. 2, I, A), acting on a calibrated spring (B). The displacement of the membrane according to pressure is mechanically amplified and converted into the movement of a pen (C) recording on a clockwork-driven paper recorder (D).



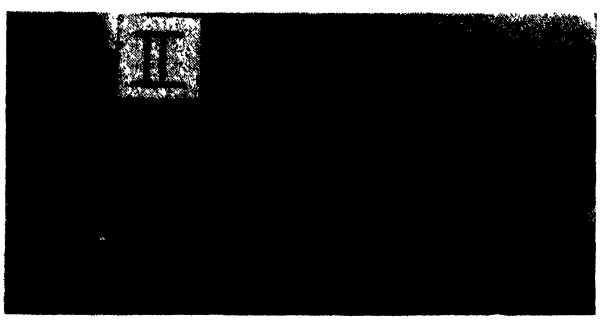


Fig. 2. Construction drawing (I) and photo (II) of the recording depth meter.

Combined recording depth and temperature meter

This instrument (Fig. 3), which basically is very much like a "Bathythermograph", is intended to measure the water temperature at the depths where fishing gear is being operated. By investigating the amount of catch versus temperature and depth, correlations can be found which may be very useful as a guide for locating profitable fish concentrations. As usual, the depth is determined by measuring and recording the hydrostatic pressure. For the temperature, a liquid thermometer is used. In order to increase accuracy, it has a particularly long, and therefore coiled, tube filled with a temperature sensitive liquid. The variations of the volume of the temperature sensitive liquid in the capillary tube are measured by bellows and recorded by a mechanism similar to the depth meters. Fig. 4 gives an example of a combined record obtained with this instrument.

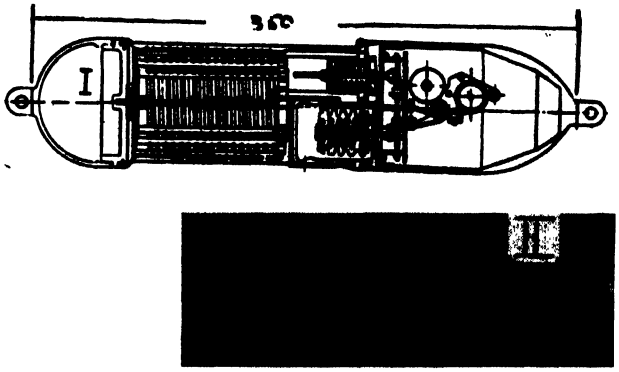


Fig. 3. Construction drawing (I) and photo (II) of the recording depth and temperature meter.

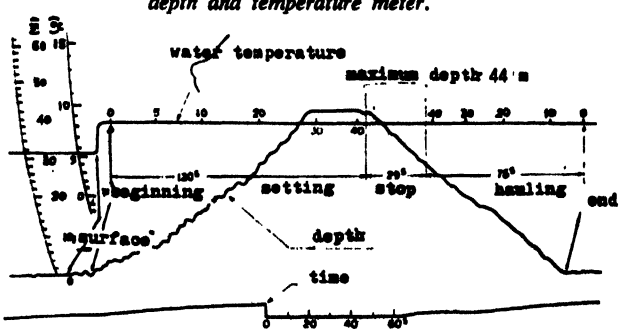


Fig. 4. Example of a record of the depth and temperature meter.

Fig. 5. Schematic principle (I) and photo (II) of the recording current meter.

Recording current meter

This instrument (Fig. 5) is mainly used for measuring the actual speed of a trawl through water. It may also be utilised to determine the difference of water flow inside and outside a trawlnet. In principle, this instrument is a resistance log, i.e. the towing speed is deduced from the towing resistance of a specific body, in this case a sphere of 10 cm diameter. Before choosing this principle, the envisaged range of speed and water temperature variation in regard to Reynold's number was considered, to make sure that the coefficient of resistance of the sphere would be constant. It was found to be 0·45. The sphere is made of brass (Fig. 5, I, 3) and has a buoyancy of 360 g. It is connected with the recording balance, measuring its towing resistance by a 0·3 mm diameter not too rigid piano wire (2). The indicating mechanism of the spring balance (4) is specifically designed so that the resistance values are converted into indications of a pointer (5) with linear correlation to the speed. The pointer records on a clockwork-driven paper recorder (6). The whole balance and recording mechanism is installed in a lightly built container made of "Hydronarium" and the movements of the piano wire, in connection with the lever of the spring balance, are transferred from the outside through an elastic diaphragm (1). The part of the container separated from the outside by this diaphragm is filled with silicone oil to provide resistance against corrosion and water pressure.

Recording underwater dynamometer

With such dynamometers, the tension on various lines and ropes of fishing gear can be measured underwater. By combining the measurements of such instruments at several points underwater, and also on board the trawler, the relative share of different parts of the gear in the total towing resistance can be determined. In principle, the instrument is a hydraulic dynamometer (Fig. 6) in which the pressure created by the pull on the rings A and B (Fig. 6, I) on the piston (C) in a cylinder is measured by a bourdon tube (D) and, after mechanical amplification, recorded by the pen (E) on a clockwork-driven paper recorder (F).

Dynamometer for trawl warps

This instrument is a combination of a spring-type dynamometer with electrical transmission from meter to indicator (Fig. 7). The indicator is a type of ammeter.

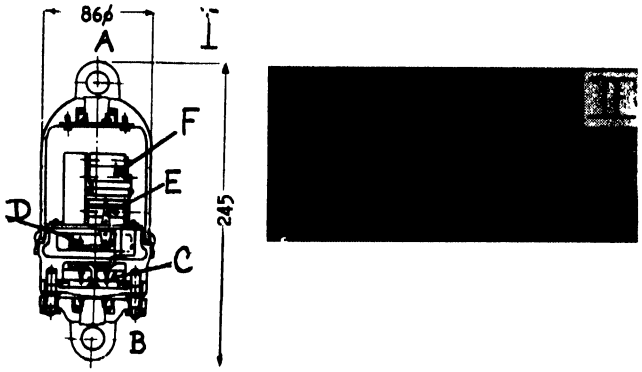


Fig. 6. Construction drawing (I) and photo (II) of the recording underwater dynamometer.

Record groundrope indicator

This instrument is meant for measuring the curvature of the groundrope of bottom trawls. For this, several such instruments have to be distributed over the groundrope for simultaneous measurement. In principle, the instrument (Fig. 8) measures and records the angle between a free movable external lever (A) and the axis of the instrument which represents the direction of the groundrope at the point of attachment. The recording part is installed in a water- and pressure-tight casing.

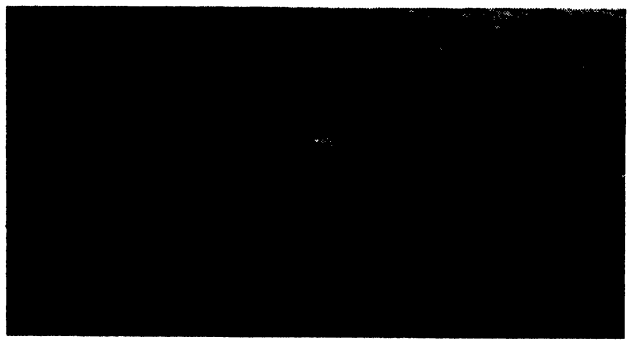


Fig. 7. Dynamometer for trawl warps in measuring position.

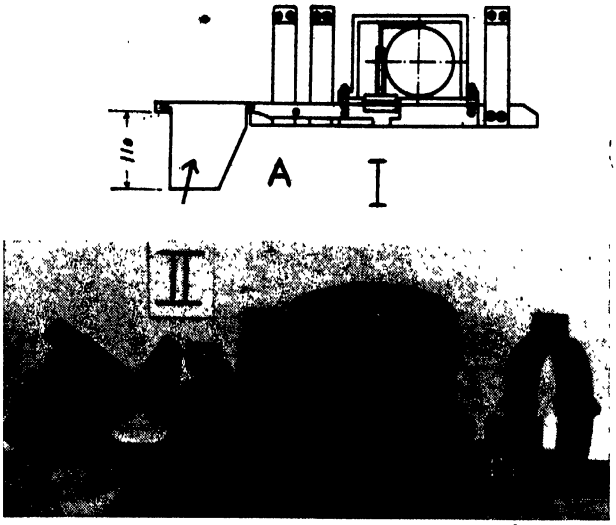


Fig. 8. Recording groundrope indicator.

.ow-speed log for trawlers

'or research on trawl gear, the towing speed must be .nown accurately. Since ordinary logs are not accurate nough at the low speeds normally used in trawling, the uthors designed and constructed a new type of log for rawlers. In principle, this log measures the water speed ıy the revolutions per unit of time induced by the water low on a calibrated propeller which is towed by the rawler. In order to maintain the propeller in a stable ıosition, it is installed in an aeroplane-like stabiliser Fig. 9). The propeller revolutions are transmitted to the ndicating unit on board the trawler through an electric able. For measurements, the propeller is towed in 10 m vater depth, which requires different lengths of towrope or different speeds.

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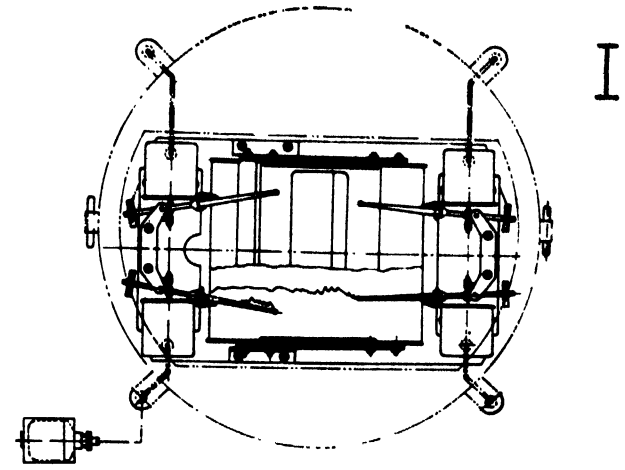
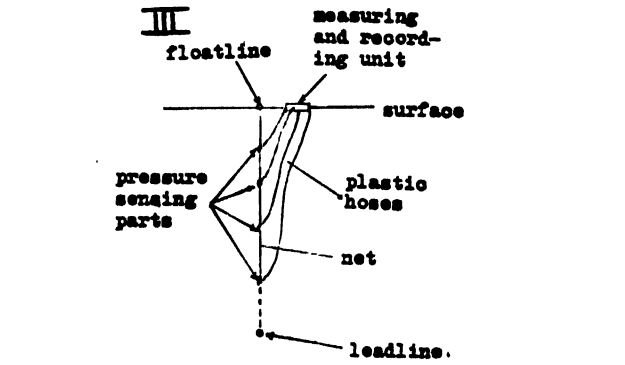
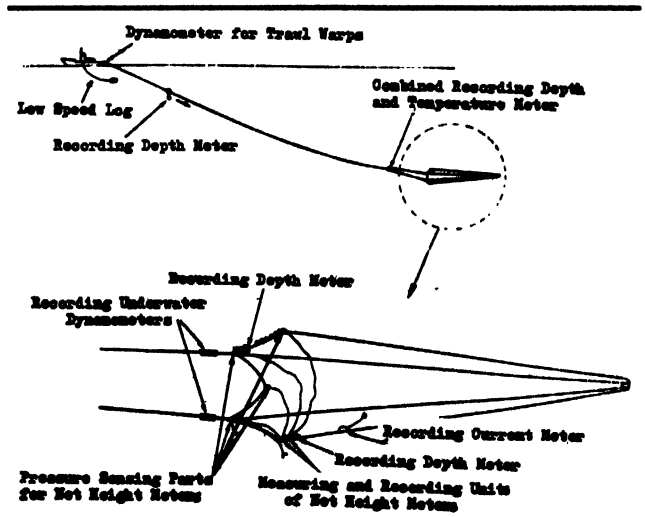
Fig. 9. Low-speed log for trawlers.

Top Right) *Fig. 10. Schematic principle (I) and photo (II) of the ecording depth meter for gillnets. Example for the application of this instrument to a gillnet (III).*

Bottom Right) *Fig. 11. Example for the determination of some nain characteristics of a trawl by applying several of the described measuring instruments simultaneously.*







Trawl Studies and Currents

Abstract

Trawl instrumentation can be very sophisticated and expensive so there is a lot to be said for the instrument that is simple in principle. Two such instruments are the Jelly-Filled Directional Rolling Inclinometer and the Pisa Current Indicator, both very simple in construction and operation. They are based on the solidifying of a jelly in a container, thereby freezing indicators in operational position. The jelly sets after half an hour or so, giving readings in the vertical and horizontal planes of the angle of the wire to which it is attached. Various uses are discussed; the indication of trawl warp curvature, the indication of trawl headline height and measuring the bends in a line of driftnets under the action of the tide. It is pointed out that bottom and surface currents may be quite different and this can often cast doubt on the reliability of instrumented gear testing results. In particular, the query is raised as to just what is meant by the water speed of a trawl. Carrying a small circular compass, the Pisa tube is a 'Pyrex' bottle filled half with jelly and half with castor oil; it is used for measuring the direction and rate of bottom currents. It can be used down to 750 fm (1,370 m). Other than its obvious use in gear testing, it is suggested that it may give useful clues on the orientation of fish schools at the bottom where they often lie strung along the tide.

Mesures de courant et études de chalut

Résumé

Les instruments utilisés dans les études de chalut peuvent être très compliqués et onéreux et il serait intéressant d'avoir des instruments de construction simple. Le "Jelly-Filled Directional Rolling Inclinometer" (inclinomètre directionel) et le "Pisa Current Indicator" (indicateur de courant) sont deux instruments de construction et d'utilisation simples. Ils sont basés sur la solidification d'une gelée. Les instruments placés dans un flaconcontenant cette gelée sont fixés dans leur position d'opération lorsqu'au bout d'une demi-heure environ, la gelée se solidifie. Le premier permet de lire les angles horizontaux et verticaux pris par la partie de l'engin sur laquelle a été placé l'indicateur. Différentes utilisations sont examinées: l'indication de la courbure des funes; l'indication de la hauteur de la ligne de tête; la mesure des courbes prises par les filets maillants sous l'action des courants. Il est signalé que les courants de fond et de surface peuvent être très différents ce qui peut faire douter de la véracité des résultats obtenus pendant les essais instrumentés d'engins de pêche. La question est aussi posée de savoir ce qu'on veut réellement dire par vitesse de l'eau d'un chalut. Le "Pisa Current Indicator" est un flacon en 'Pyrex' rempli moitié avec de la gelée, moitié avec de l'huile de ricin et où flotte un petit compas circulaire. Il est utilisé pour mesurer la direction et la vitesse des courants defond, jusqu'à des profondeurs de 1370 mètres (750 brasses). Il est suggéré en outre que cet instrument peut donner des indications utiles concernant l'orientation des bancs de poissons près du fond où ces bancs sont très souvent alignés avec le courant.

Instrumentos para hacer pruebas con artes de arrastre

Extracto

Los instrumentos empleados para los experimentos con artes de arrastre pueden ser muy costosos y complejos, por lo que tienen grandes ventajas los sencillos y baratos. Dos de éstos son el Jelly-Filled Directional Rolling Inclinometer (un inclinómetro lleno de jalea) y un correntómetro marca Pisa. Se basan en la solidificación de una jalea al cabo de unos 30 min. que inmoviliza unos indicadores de posición y señala los ángulos vertical y horizontal del cable al que se sujetan. Se explica su uso para determinar la curvatura del cable, la altura de la relinga de corchos del arte y los senos que por efecto de la corriente forma una andana de redes de deriva. Se menciona que las corrientes del fondo y de la superficie pueden ser totalmente distintas, lo que con frecuencia hace dudar de la seguridad de los resultados de ensayos con instrumentos en las redes. Pregunta el autor qué se da a entender cuando se habla de la velocidad de un arte de arrastre en el agua. El correntómetro Pisa es una botella de 'Pyrex' la mitad llena de jalea y la otra mitad de aceite de ricino, con una pequeña brújula circular, que se emplea para medir la velocidad u dirección de la corriente en el fondo y puede usarse a profundidades hasta de 750 brazas (1.370 m). Además de su uso directo en las pruebas de artes, puede dar información de utilidad respecto a la orientación de cardúmenes de peces en el fondo, en el que con frecuencia se encuentran situados en la dirección de la corriente.

by

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IT is of course an inevitable feature of studies made on the behaviour of commercial fishing gear that investigations can be carried out only by the relatively small number of persons who possess the essential facilities. Apart from the major expense (the ship), large sums of money are represented by the trawls, whether these be for bottom or midwater fishing. Furthermore, if studies of the geometry of towed trawls are to be made whilst they are actually fishing, there is the added expense of electronic telemetering gear and that represented by the salaries of the specialists who are needed to use it. All in all, there is so much both of expense and complexity that the studies of trawl behaviour have necessarily become very much of a closed shop—which surely is not all to the good! Outsiders, who may incline to credit themselves with a few ideas thought to be potentially useful, must needs tread very warily when airing views on such an important subject of which they can have had little if any experience.

It would be quite wrong, however, to suppress such ideas when, given a little courage, the chance offers to

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Recording depth for gillnets

The principle of this instrument is a combination of the principles used for the recording net height meter and depth meter described above. It is designed for simultaneous measurement at four points. Four pressure sensing parts with plastic bags are connected with separate plastic hoses, each to its own bellows and pointer indicating system for recording on one common, larger sized, clockwork-driven paper recorder. The measuring and recording unit is installed in a watertight metal case which floats at the surface. Fig. 10 shows a schematic drawing of the measuring and recording unit with one pressure sensing part (I), a photo of the whole instrument (II) and an example for application at a gillnet (III).

A wireless net depth telemeter is also used and is described elsewhere.

advance them—as it now does at this present congress.

Presumably, the search for the best trawl requires successive trials as different components within the total assemblage of towed gear are modified and as various fitments are incorporated. Granted that the sophisticated instrumentation possessed by the specialist investigators can telemeter back to them aboard ship all the parameters of interest as the trawl is towed through the water at varying speeds and with different lengths of warp veered, there nevertheless remains one disquieting consideration.

If all the studies designed to promote the progressive improvement of a trawl's aperture or towing characteristics were made in a large body of motionless water, then it would be admissible that all inferences made as to the influence of introduced modifications would be justified. As regards net studies carried out in tidal seas, it is a matter for surprise not to have come across any reports wherein adequate attention has been paid to the possible effects of intrinsic water movements. If, for instance, between two successive tests the angle of door attack had been altered, how can it be safe to assume that a discovered change in the net's shape or resistance is attributable solely to that alteration unless it be known that the water on the bottom was moving exactly the same (speed and direction) during the two experimental tows? In saying this we are assuming that the work is being carried out in the open sea where tidal streams may reign or where at least there may be notable currents—perhaps even a stratification of currents differing in speed and direction at one and the same time. It has, of course, been fully recognised that "conditions are never exactly repeatable from one tow to the next as regards ground and tide", and the need has been expressed for "a more accurate instrument to measure water speed at the trawl".

The word "accurate" is a tricky one indeed when applied to current measuring at sea, as is well realised by all who have spent long years on that job, and what is meant by the expression "water speed at the trawl" also gives one to think.

There are two hard facts about water speed as related to trawling and both could be catered for. One is the actual movement of the water itself over the ground, which ought to be (and could be) known during trials in terms both of speed and direction. The other is the (so to speak) negative or "manufactured" current due to the travel of the ship and therefore of the trawl which follows it. The former can be measured vectorially by simple instrumental means and the latter can also be very acceptably assessed vectorially. One way for the latter is to follow the method so much in vogue nowadays with oceanographers who take constant radar bearings upon an anchored buoy—or better on a pair of anchored buoys. The naval surveyors' taut wire method would be ruled out because of the presence of the trawl behind the ship. We are here thinking of course of work in the open sea away from the convenience of shore sights which might offer in certain regions. What would be the meaning (and therefore the permissible application) of the showings of a current-measuring instrument mounted on or within a trawl is difficult to appreciate and it would require much space to discuss the point fully.

As regards the actual movement of the water itself, a good deal can of course be done by making comparative tows when the surface water would expectably have the same movement as judged from tidal stream atlases. Even for the surface water the matter is fraught with difficulty despite the recent appearance of excellent new presentations of the tidal streams around Britain. The ratios of stream speeds at syzygies, quadratures, and intervening times have been regionally plotted on charts, and so too have the angular spreads of the streams in various areas. It would, therefore, be possible to work in a certain area and to assume that at "x" hours away from reference high water time on one day, the stream on the surface would be the same as at "y" hours away from the same reference tidal state on another. To a specialist in current measuring, however, there would seem to be no escape from the need to do trawl tests in still (or virtually still) water if certainty has to attach to inferences made regarding the influence of incorporated modifications.

If, as may well be the case, there is a stratification of currents different in speed or direction (or in both at the same time) the situation will be further bedevilled. This might well apply also in a region where the tidal streams are almost always in the same direction all down through the column if they nevertheless change direction out of phase somewhat at the different levels. The worst situation of all, however, with stratified currents heading differently at differing speeds, will arise from depth considerations. The longer the towing warps, the greater will be the difficulties introduced.

The point of the remarks so far made is merely to emphasise the need to take the environment into proper consideration when tests are made of trawl behaviour and geometry aimed at gear improvement.

The writer has no experience whatsoever of, and next to no knowledge of, the sophisticated electronic telemetering gear used by the ingenious specialists whose charge it is to make the studies aimed at the production of the best trawl. However, because of the troubles and doubts involved for the reasons sufficiently touched upon already, he wonders whether his own very simple device which does not telemeter but merely reveals after recovery of the gear how a trawl was shaped, and how its warps, etc., were sloped (azimuth and obliquity) during a settled-down tow, might not be of more use than hitherto considered. The device in question—the "Jelly-Filled Directional Rolling Inclinometer"—has now been even further simplified (see Appendix). Besides being able to reveal what had been the headline shape in the vertical plane, it can also reveal the same in the horizontal plane. Also, besides being able to reveal divergence and slope along the warps at as many points as instruments might suffice for, the simple tool could undoubtedly be used to reveal headline height as well—all this of course *a posteriori*.

Tests once made with a former version of it on a

midwater trawl towed through the virtually still waters of Loch Ness, revealed that the net had towed away from dead astern with one door somewhat higher than the other and with the net not "square" to the direction of tow.

Though we are here dealing with trawls, it is perhaps permissible to give a passing thought to certain recent work of great interest on the driftnetting of herring. The bare bones of this important work has been the discovery of the significance attaching to whether the driftnets lie streamed true "in the tide" or are disposed to some degree athwart it owing to windage on the vessel.

Because the reported research attested considerable hard work, it is perhaps worth stating here that it would be very simple indeed to measure the lie of driftnets (not in sight) with regard to the magnetic meridian and at the same time to reveal whether there had been an urge of water through them from one side or the other —and, if so, at what angle.

This could be done with no difficulty at all using a couple of Pisa Current Indicators (see Appendix).

We have so far said nothing whatsoever about fish behaviour. This is a very big subject indeed and one which is wisely left to specialists in keeping with the old adage that fools rush in where angels fear to tread. However, one or two relevant remarks can be made here without the assumption of any worthwhile knowledge of the subject.

The first is to refer to the full recognition on the part of the expert gear specialists that, no matter what they come up with by way of a "best trawl", whether or not it makes the hoped-for big catches will depend very markedly upon the behaviour of the fish it aims to catch —fish which may have been "seen" on the echo sounder or asdic set before shooting and which also may still be "seen" as the net is conned to take them. When speaking above of trawl trials it was not necessary to advance hesitant opinions about the importance of currents; assertions could safely be made. Though it is not possible to speak nearly so positively concerning any connections between currents and fish behaviour, enough is known about bottom currents in some regions to make it seem at least likely that they will influence fish behaviour on certain grounds. It has been written of herring (by F. R. Harden Jones) that "shoals which appeared to hold their position in the daytime must have been stemming the tide, and the sensory stimulus involved was probably a tactile or visual clue from the bottom to the fish nearest to it. Fish out of touch and out of sight of the bottom might use the first fish as markers and maintain their position relative to them."

This provokes various thoughts. The first is that for all his wisdom and lore there is one thing which the most experienced skipper does not know and that is the speed and direction of the bed current at the time he shoots. If he knew this he would presumably know the direction in which the on-bottom fish would be heading and there might well be profit in trying the results of approaching them along different courses as between different tows. The writer is surprised that in the long records of fisheries research he can turn up no records of experimental trawl hauls having been carried out with a knowledge of on-bottom current. It is easy to investigate the latter and it would seem at least worth a trial to discover whether benefit might not accrue from approaching the fish at various angles to their lie as this might be dictated by the direction of the bed current.

Recent work devoted to the observation of sea bed currents has shown that, in areas where the ground is highly convoluted, the current may give rise to considerable turbulence when on certain headings. In such cases it seems reasonable to expect that on-bottom fish might well mill about under conditions of impaired vision and be more prone to capture in the resulting silty water. Perhaps the day may come when, besides having atlases of surface tidal streams presenting the water movements at hourly intervals from a stated reference hour, we may seek to produce the same for the bottom water movements as well. If it ever does, a start could be made most easily with the North Sea.

APPENDIX

(1) The Jelly-Filled Directional Rolling Inclinometer

This simple device, illustrated by Figs. 1 and 2, remains very much what it was when described in the Fishing News (issue of 23rd September, 1960). Since that time, however, the contained compass has been much improved and is now mounted centrally within the cylinder. A new method of attachment has been devised which, apart from being easier, affords a longer setting time of the initially-hot jelly and provides a protective cover to the 'Perspex' cylinder

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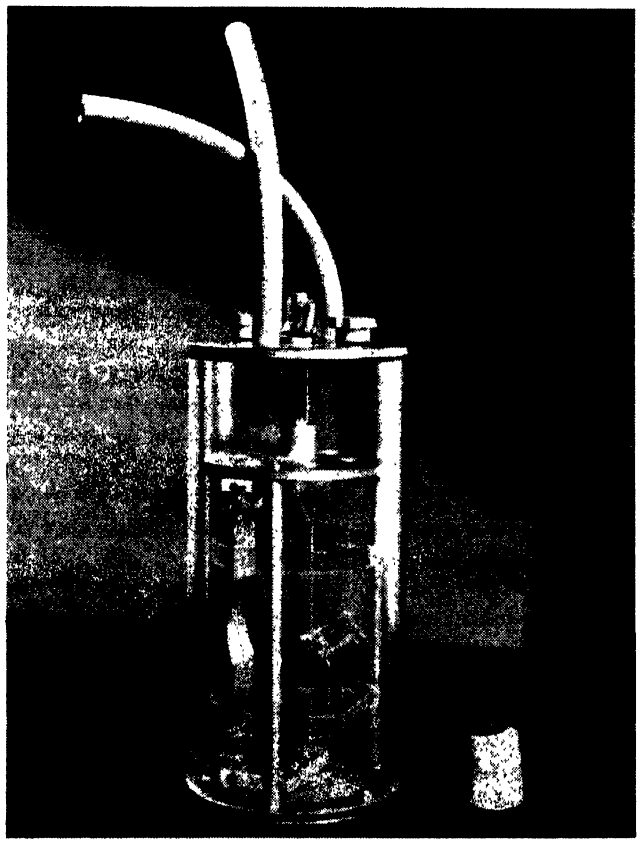

Fig. 1. The Jelly-Filled Directional Rolling Inclinometer empty and without casing.

Performance of the Granton Trawl

Abstract

This paper describes instrumented gear testing of the heavy 78-ft headline, 120-ft groundrope, Granton trawl used by the Humber Fleet. The first drawing shows details of the trawl. It is rigged with iron bobbins for half the length of the groundrope. The second drawing shows where the deck instruments, the warp tension meters, warp divergence, declination and heel meter are situated. All these, plus the speed log over the side, the ship's Chernikeef log and engine rpm are recorded electrically on a panel situated in the research ship's laboratory. A propeller thrust meter is also installed on the ship. Underwater loads are measured in front of and behind the otter boards, also in the headline and toe legs. Headline height is measured on a manometer; headline spread by an electro-acoustic instrument. The true spread between otter boards is measured on an electronic-acoustic instrument. There follows a general picture of the shape of the trawling gear as found by these instruments showing how the warp declination was 25° at the surface and only 11° at the otter boards. The true spread between the otter boards is 218 ft; a 15 per cent augmentation over the spread as obtained by surface measurement. The main harness lines of the net lying in the shape of a catenary give a headline spread of 49½ ft, with an overhang between headline and groundrope of 24 ft. The load measuring instruments show how the drag of the gear can be broken down from the seven-ton total into 58 per cent for the net and appendages, three per cent for sweeplines and danlenos, 29 per cent for the otter boards and 10 per cent for the warps. Values as high as 25 per cent of the total shearing force of the otter boards have been measured as arising from ground shear rather than hydrodynamic force. The ship's thrust curves against towing speed over a range of propeller rpm, with the trawl drag plotted across them, is illustrated and described as a powerful tool in gear research.

by

W. Dickson

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Performance du chalut Granton

Résumé

La communication décrit les épreuves instrumentées du chalu Granton de 24 m de ralingue supérieure et trois m de ralingue inférieure utilisé par la flotte Humber. Les détails de la construction sont donnés sur le premier dessin. La ralingue inférieure du chalut est grée en son milieu, avec des rouleaux sur la moitié de la longueur. Le second dessin indique la position des instruments de pont, des tensiomètres de funes ainsi que des instruments servant à mesurer les angles d'inclinaison et de divergence des funes. Les indications données par ces instruments, par le loch de côté, le Chernikeef loch et, le nombre de t.p.m. de la machine, sont enregistrés électriquement sur un tableau situé dans le laboratoire du bateau de recherche. Un indicateur de la puissance de poussée de l'hélice est aussi installé sur le bateau. Les forces sousmarines exercées devant et derrière les panneaux sur la ralingue supérieure

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to minimise risk of scoring. The 'Perspex' cylinder, 8¼ in long and 4 in wide, is now pushed into a tube of common vulcathene (¼-inch thick) which is just a trifle too small to admit it until slit full length (16 in) by one cut. Using a couple of transfixing bolts seated in large washers it is arranged that the inclinometer can be speedily bound on to a cable by means of two separate short lengths of trawl twine as shown in the second photograph. Within reason, the vulcathene tube can be as long as wished in the interests of directional indications.

Naturally, when the attachment is to a "slippery" warp, it is wise to secure a bulldog on the latter between the points where the two lashings are to be made. The filled device, which weighs only 2¾ lb in water, allows ample time for a shot trawl to settle down because, if attached on deck whilst very hot to the headline (or other component of the gear), everything will still be free after half an hour's submergence even in water as cold as 0·7°C. Under the most usual conditions the inclinometer jelly will have set firmly before the end of a normal tow. After recovery the inclination can be read off directly from the protractor within the tube and the azimuth of the slope got from the "frozen-in" compass.

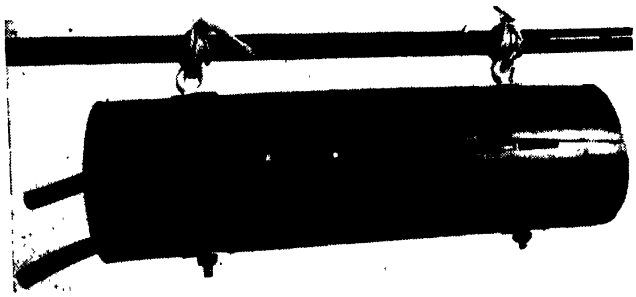

Fig. 2. The Jelly-Filled Directional Rolling Inclinometer encased and rigged.

(2) The Pisa Current Indicator

This is a well-tried device for extending the depth of use of the simple "Current Measuring Bottle for Fishermen" described and figured in the Fishing News (issue of 12th May, 1961). Its indicating unit is a 'Pyrex' bottle filled half with jelly and half with coloured castor oil which, not being buoyant, is used fixed within a 40-inch long tube of low density polythene. With the filled bottle within it, this latter stands erect in motionless water when submerged whilst fastened at its lower end to a weight with a limp tether consisting of six inches of thin strong twine. Because the bottle has to be hot when initially sent down into the sea and has to cool down under pressure when anchored on bottom under a considerable head of water, it has a flexible rubber diaphragm in its cap to accommodate for changing volume of contents. There is a strong circular compass within the bottle. This hangs on a thin 'Terylene' thread from the tip of a rod which runs axially down the bottle from a seating in the underside of the screwed-on brass cap.

It is arranged that the device goes down into the sea with not only the bottle hot (and the jelly therefore liquid), but with the entire polythene tube filled with hot water as well. This provision greatly extends the depth of use because it prolongs the setting time of the jelly. The instrument is used whilst the ship is adrift and, when bottom is reached, the sudden removal of a thin rubber "hat" from the top of the tube voids the warm water envelope to expose the bottle to the cold water down below. There is a provision whereby the tube remains at anchor undragged by the drifting ship until enough time has elapsed for the jelly to set. This is achieved by means of a pay-out line which is an adequate length of strong nylon braid spooled within a box of hard plastic carried by the bottoming gear.

On recovery, the speed of the bottom current is got by referring to a calibration curve the degree of slope of the interface between the set jelly and the coloured oil. This latter is easily measured through the glass by means of a protractor or special angle-measurer. The direction of the current is got by referring the "uphill" direction of the set jelly slope (as the cold bottle stands on its base) to the "frozen-in" hanging compass.

Whereas the original (and still much-used) simple current-measuring bottle for fishermen can be used down no farther than about 60 fm, the Pisa Current Indicator just described in brief can operate to well beyond 750 fm for the measurement of bottom currents.

A new variant of it, of no interest here, can be used down to all depths.

et aux points d'attache des entremises sont également mesurées. Un manomètre indique la hauteur de la ralingue supérieure et un appareil acoustique électronique permet de mesurer l'ouverture horizontale et l'ouverture réelle entre les panneaux. La communication décrit ensuite l'idée générale de la forme prise par le chalut, d'après les données de ces instruments, montrant que l'inclinaison des funes était de 25° à la surface et seulement de 11° aux panneaux. La véritable ouverture entre les panneaux est de 67 m, soit en augmentation de 15 pour cent sur l'ouverture calculée à partir de l'angle de surface des funes. Les ralingues prennent une forme de caténaire et donnent une ouverture de 15 m. Le dépassement du dos sur la ralingue inférieure mesurait 7,5 m. Les tensiomètres montrent que la résistance globale de sept tonnes de l'engin peut être décomposée en 58 pour cent pour le filet et ses accessoires, trois pour cent pour les bras et les danlenos, 29 pour cent pour les panneaux et 10 pour cent pour les funes. De la force latérale totale des panneaux, 25 pour cent provenaient de la résistance du fond et 75 pour cent de forces hydrodynamiques. Les courbes représentant la poussée de l'hélice par rapport à la vitesse de touage pour différents t.p.m. avec la résistance de l'engin en résultant, sont données graphiquement et constituent un instrument précieux pour la recherche d'engins de pêche.

Funcionamiento del arte Granton

Extracto

Describe el autor los ensayos realizados con auxilio de instrumentos, del pesado arte de arrastre Granton, de 78 pies de relinga alta y 120 pies de burlón, empleado por la flota pesquera del río Humber. El primer esquema muestra los detalles del arte con las bobinas de hierro que lleva la mitad del burlón; el segundo esquema da la posición que ocupan en cubierta los diversos instrumentos, comprendidos los medidores de la tensión, divergencia e inclinación de los cables. La información dada por los tres instrumentos, así como la de la corredera normal y la corredera Chernikeef y las revoluciones del motor se indican eléctricamente en un cuadro situado en el laboratorio de investigaciones del barco, el que también cuenta con un medidor del empuje de la hélice. Las cargas submarinas se miden delante y detrás de las puertas del arte, en la relinga de corchos y en los extremos inferiores delanteros de las pernadas. La altura de la relinga alta se mide con un manómetro y la abertura con un instrumento electroacústico. La verdadera separación entre las puertas de arrastre se mide con un aparato acústico electrónico. Sigue una descripción general de la forma del arte determinada por estos instrumentos, que demuestra que el ángulo que forman con la horizontal los cables de arrastre es de 25° en la superficie y de solamente 11° en las puertas. La verdadera separación entre las puertas es de 218 pies, distancia superior en un 15 por ciento a la lograda con medidas tomadas desde la superficie. Las relingas principales de la red, en forma de curva catenaria, dan a la de corchos 49,5 pies, quedando ésta de 24 pies por delante del burlon. Los instrumentos para determinar la caga muestran que la resistencia que ofrece todo el arte, con un total de septo tons, se descompone en un 58 por ciento para la red y sus apéndices, un tres por ciento las malletas y los calones, un 29 por ciento para las puertas y un 10 por ciento para los cables. Se calcula quehasta un 25 por ciento de la fuerza de separación de las puertas la causa la resistencia del fondo más bien que la fuerza hidrodinámica. Las curvas de empuje del barco con respecto a la velocidad de remolque a diversas r.p.m. del propulsor, con la resistencia del arte trazada a través de ellas, se ilustra y describe como un arma poderosa en la investigación de los artes.

THE instruments described in Mr. Nicholl's paper "Trawl Gear Instrumentation and Full-Scale Testing", have been used to measure the operating dimensions of several different kinds of trawl, but chief among those was the Granton trawl. The study of the recorded dimensions led to theories relating the operating dimensions one with another and from there on to the design of new trawling gear. This paper is largely confined to describing how the performance of the well-known Granton trawl (Fig. 1) was measured and what was learned from it.

The positions of the instruments on the ship and trawling gear are shown schematically in Fig. 2. Not all the instruments were mounted on the trawl every time, but always enough to investigate the particular aspect of trawl behaviour being studied during that haul. The instruments used fall under four headings: (1) those pertaining to the ship; (2) the deck instruments; (3) underwater electro-mechanical instruments and (4) underwater electronic-acoustic instruments.

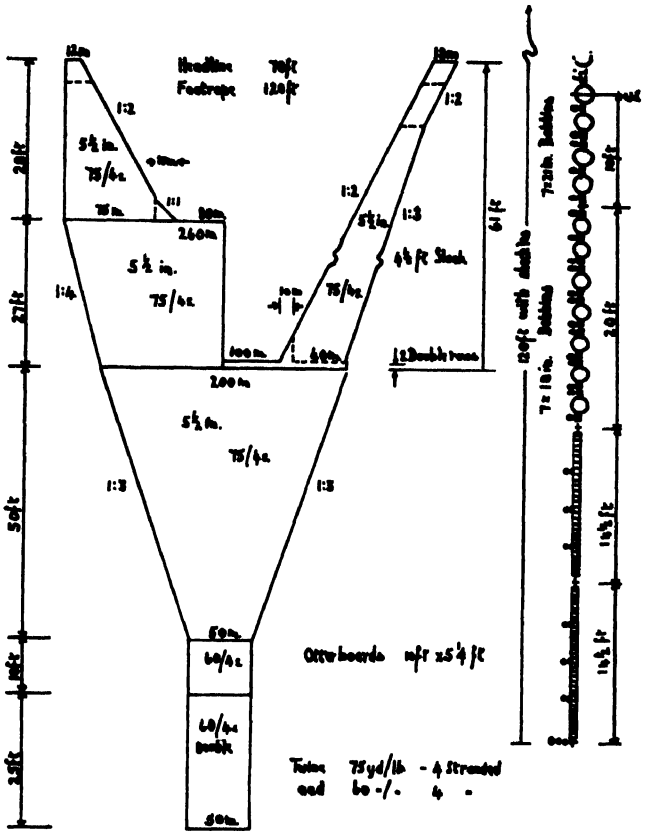

Fig. 1. Granton trawl.

The ship instruments comprised: echo sounder, Decca Navigator, Chernikeef log and rpm counter. Later a Michell thrust meter was fitted to the thrust block.

The deck instruments comprised: the three-wheel strain gauge tension meters fitted to each warp, the combined warp divergence, declination and angle of heel meter, as well as the Kelvin Hughes speed log towed over the side. All these instruments recorded their readings on a centralised control panel and later it was arranged so that engine rpm and the speed by the ship's Chernikeef log could also be recorded on this control panel.

Underwater electro-mechanical instruments comprised: the large and small load cells for tension measuring and for measuring the otter-board forces, the otter-board angle of attack and angle of heel meters, the headline height manometer, the underwater speed log and an angle meter used for measuring warp declination angles near the bottom and also at times used to measure the angle of pitch of the otter boards.

Electronic-acoustic instruments—two spread meters were used, one to measure directly the distance between

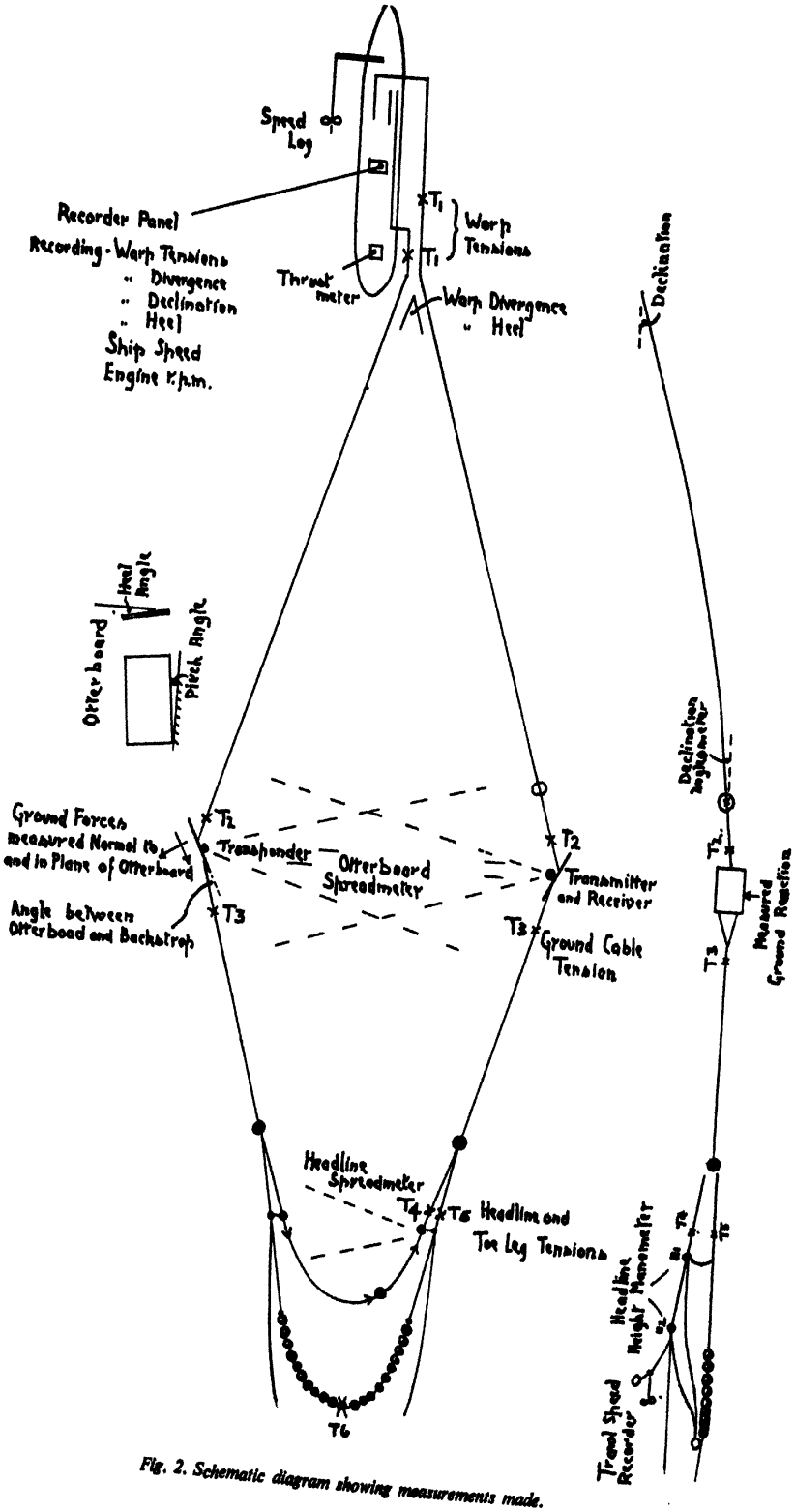

Fig. 2. Schematic diagram showing measurements made.

the otter boards and the other the spread between the headline ends. It was later found more practical to measure the spread 25 fm up the warp from the otter boards, and to adjust this measurement to give the true spread between the otter boards.

Drag breakdown

The measurements of tension at the various points indicated in Fig. 2 give the following breakdown for the load in the various parts of the trawl gear. It is given for a towing speed of $3\frac{1}{2}$ knots, at a depth of 100 fm and using 325 fm of $3\frac{1}{4}$ in circumference warp.

Netting and net appendages	4·1 ton	58%
Ground cables (sweeplines) and danlenos	0·2	3%
	4·3 ton	
Otter boards	2·0	29%
	6·3 ton	
Warps	0·7	10%
	7·0 ton	100%

The 58 per cent due to the drag of netting and net appendages can be further split up into 48 per cent due to the netting and 10 per cent due to the appendages, i.e., bobbins, groundropes, headline and the 60 floats. This further subdivision was deduced more from the results of tank testing than from measurements at sea and it also provided an estimate of the friction of the net appendages as three per cent out of the 10 per cent.

The breakdown gives a lead on where to set about attempting improvements; the effort should be directed to cutting down the percentage of the drag that goes into warps, otter boards, net appendages and friction and so pushing up the percentage that goes into the fishing parts, the ground cables (sweeplines) and the net. The breakdown also helps in setting a reasonable overall limit to the possibility of drag improvement with any gear that is at all similar. This is done by setting realistic targets for reduction in drag of each of the unwanted items and then re-summing and re-allocating the percentages.

Angular measurements and planform

The measurement of angles together with the known lengths of the various parts of the gear, give the broad picture of the gear in the fishing position as shown in Fig. 3. From this, and corrected for the true spread as given by the acoustic spread meters, the planform of the main harness lines can be drawn up as in Fig. 4. The shape of the headline and the bobbin part of the groundrope agree fairly well with the shape of a catenary, which makes the planform susceptible to mathematical treatment. It was from the drag breakdown and a knowledge of the angles, that tables could be prepared showing the performance characteristics of warps when trawling and related to this was the question of otter board behaviour.

Otter board behaviour

It was only over a relatively narrow range of speed, around $3\frac{3}{4}$ knots, that the otter boards were substantially upright. At $2\frac{3}{4}$ knots they were heeled 15° top inwards and when speed was raised to $4\frac{3}{4}$ knots they were heeled 15° top outwards. It is perhaps chiefly for this reason that the Granton trawl has been reckoned by fishermen to fish the best at about $3\frac{3}{4}$ knots. The upward component of the pull in the trawl warps eases some of the weight of the otter board off the sea bed. The weight of an otter board in water is about $\frac{3}{4}$ ton and at $3\frac{1}{2}$ knots the ground reaction is cut down to about $\frac{1}{4}$ ton, i.e., two-thirds of the otter board weight is eased off the bottom; even so a considerable proportion of the total shearing force of the otter board can result from ground shear. Values as high as 25 per cent of the total shearing

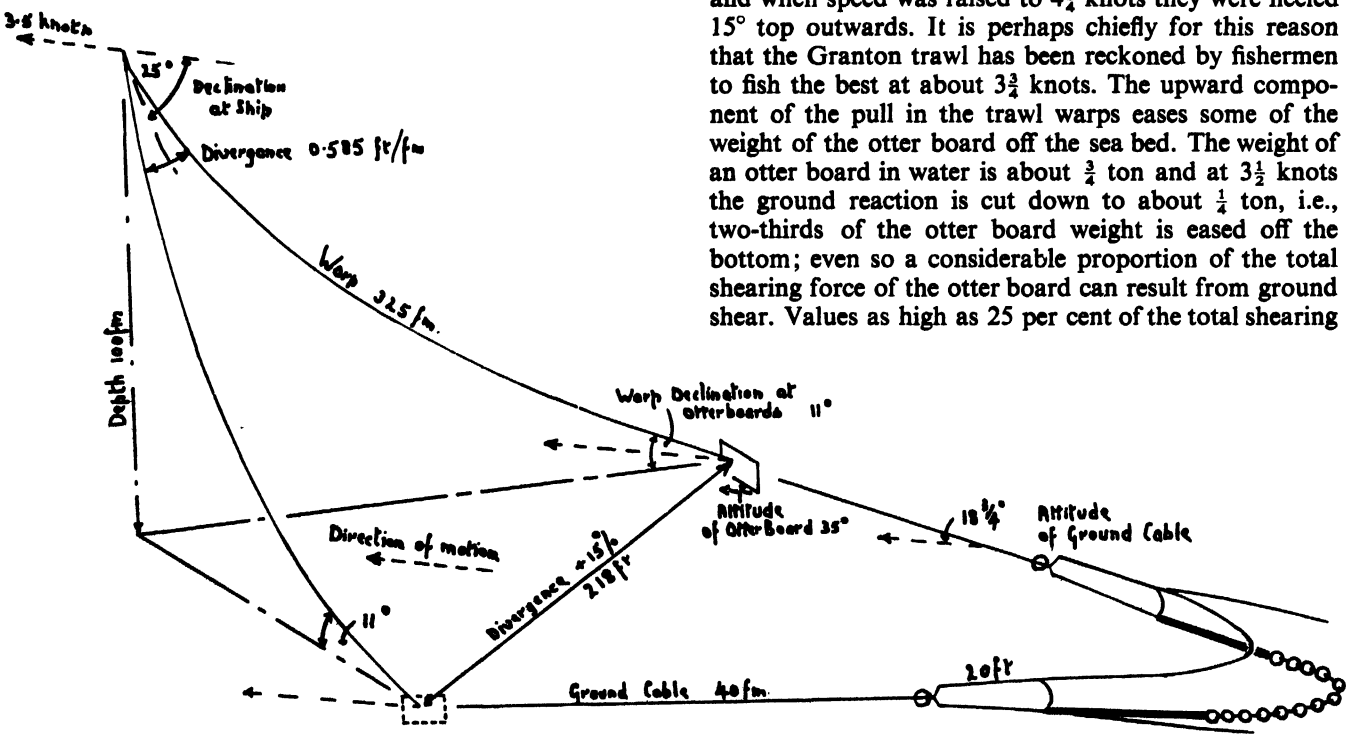

Fig. 3. Principal angular measurements of Granton trawl.

force have been measured as arising from ground shear but this figure varies with the nature of the bottom, being lower on hard ground. It follows that the lift and drag coefficients of model otter boards, as measured in towing tanks or wind tunnels, require some review under operational conditions. The emphasis in the design of new otter boards is on improving their lift to drag ratio, keeping the boards upright over a greater speed range and keeping the ground reaction large enough to profit from the ground shear, yet not so large that the boards just sink too far into soft mud.

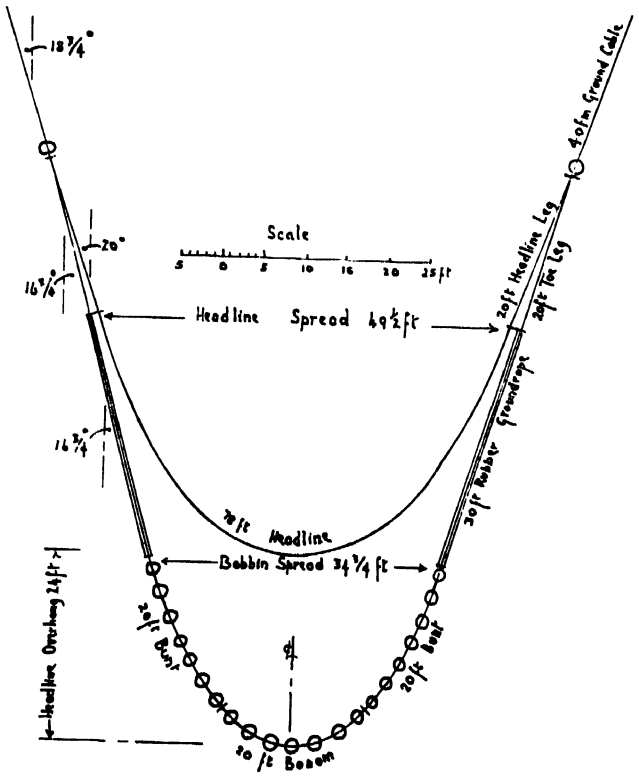

Fig. 4. Planform of harness lines.

Headline height

The headline height of the Granton trawl is poor, being only about 5 ft at $3\frac{1}{2}$ knots. Headline height is very much dependent on towing speed, falling from $8\frac{1}{2}$ ft at two knots, sometimes to as low as 4 ft at four knots. The volume of water filtered in unit time is just about the same at two knots as at four knots and for any reasonable towing speed the frontal area presented by the net is poor for the amount of netting that the net comprises.

It was not found possible to increase the headline height of the Granton trawl greatly and still keep it fishing. The short spreading wires restrict the height but lengthening these does not in itself bring much gain because of the constraint in the netting due to lack of width at the lower wing end. Extra flotation serves mainly to increase the constraint in the netting between headline the groundrope, easing the groundrope off the bottom without adding much to the headline height. Increasing the headline height up to some 15 ft requires a three-pronged attack, such as that described by Dickson (1960) but briefly involving:

(a) Altering the wire rig considerably to give very much longer spreading wires.
(b) Relaxing the constraint in the wings by reshaping them and adding more net.
(c) Increasing the flotation.

Ship thrust and trawl drag

Curves for the propeller thrust against speed of advance over a range of engine rpm can be drawn up without taking either the ship or trawling gear to sea but, while such curves are a good guide as to what to expect, it usually turns out that they are only approximate. Once a considerable number of instrumented hauls have been made with trawling gear it becomes possible to establish what the actual curves for that ship are. The experimentally derived curves for F.R.S. *Explorer* with the drag of the Granton gear superimposed, are shown in Fig. 5. Such curves, once established, are a powerful tool in fishing gear design and the matching of trawling gear to ship.

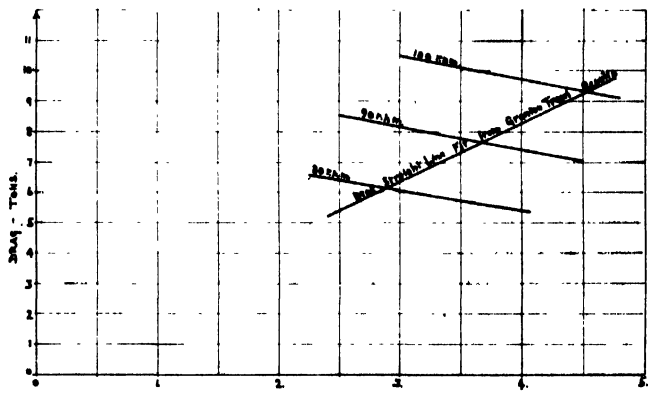

Fig. 5. Granton trawl drag—speed and rpm curves (for F.R.S. Explorer).

Discussion on Instruments for Testing Gear

Mr. W. Dickson (Rapporteur): Hamuro and Ishii describe a neat series of instruments for measuring headline height, trawl depths, speed of the trawl and an underwater dynamometer for measuring tension in front of and behind the otter boards. There is also a Recording Groundrope Indicator, several of which are, I gather, secured to the groundrope at various places. A rudder trails behind in the sand or mud; the rudder works a pen which records the angle of the groundrope at the point where the instrument was fixed. Given, say, four of these instruments on the groundrope and knowing its length you would have a good idea of its shape and spread. Does the groundrope indicator work well, I wonder? They also have a low speed log for trawlers. It is an instrument of the propeller type a measure of whose rpm is transmitted to an indicating unit aboard via an electric cable.

Speed measurement is, in fact, still one of our greatest difficulties and it can very nearly be said that you will get as many answers as the number of speed logs you like to use. It is the conditions under which they are used rather than the logs themselves which produce the variety of answers.

J. Nicholls describes a similar set of instruments, an impressive number having been evolved in the research work on trawls at Saunders-Roe's testing tank.

The measurements of otter-board shearing and drag forces just did not tie up with the otter board model tank results until a fully instrumented otter board was made. Several load cells were used to measure the ground reaction of the otter board and by a system of levers to measure also the ground forces normal to the board and in the plane of the keel.

All the deck instruments recorded electrically on a panel of six recorders. It was found that for measuring things like warp tension, which varies rapidly, even a high-speed six point recorder was not good enough. Now it is only used for measuring diesel engine temperatures, rpm and other things that don't fluctuate rapidly.

Dale and Moller show similar deck recording instruments for measuring the length of warp paid out and the warp tension of a sterntrawler.

Hamuro measured warp tension, the vessel's speed, the torque at the propeller shaft, the exhaust temperature of the main engine and the mean effective pressure of each cylinder and the fuel consumption, in order to match a new design of bull trawler to the power absorbed by controllable pitch propellers newly installed on a pair of bull trawlers.

Carruthers poses a sly question; what do we mean by "water speed at the trawl" and the supplementary question is, how do you measure it? In bottom trawling the gear is dragging on the bottom. My view of what is meant by water speed at the trawl is this: all tensions and dimensions are measured with respect to the centreline of the trawl gear, therefore velocities ought to be referred to that same direction. Because the gear is dragging like an anchor this is not necessarily the direction of motion of the trawl with respect to the bottom nor yet the direction of the ship's headings. The water speed of a trawl is, then, the component of its ground speed which lies along the gear centreline plus the component of bottom current velocity which lies along the gear centreline.

This is not the same thing as what is often taken as the water speed of the trawl, by floating a current meter on a line above the trawl headline. Such an instrument adds the ground speed of the trawl and the bottom current. What I am calling the water speed of the trawl would be more truly measured by fixing the current meter rigidly along the centreline of the gear but at some distance ahead of the net. But how does one do that and even if one did, the objection could be raised that a cross-current at the bottom made the gear slightly assymetrical about the gear centreline anyway. We might argue about this all day and still leave Dr. Carruthers with the last laugh.

Two other instruments are the netzsonde and the depth telemeter. Dr. Schärfe has discussed the former and the latter, without any wires, is described by Hamuro and Ishii. Water pressure on a pressure sensitive element is used to change the frequency of the transmitted signal which is picked up by a receiving transducer slid a little way down the warp on a short cable, far enough down to take it below the propeller wake. The National Institute of Oceanography in this country have produced a similar instrument. Now it is true that at the moment the netzsonde maybe has the best of the argument, because it gives information on fish behaviour in the net mouth and below it as well. In the long run, however, it wouldn't seem too difficult to effect a frequency change and relay information from an underwater echo sounder up to the surface.

Every winch for a netzsonde on a big trawler costs several thousand pounds so if, say, 100 trawlers were going to be fitted with netzsonde equipment it would look well worthwhile to spend a bit of money on telemeter development instead. It certainly won't be paid for with peanuts.

Once a sonic link is established for telemetering information to the surface all sorts of things begin to look possible and if information can be sent up, command signals can also be sent down. What sort of information could be sent up? In the first place perhaps research information and a likely first choice is the water speed at various places inside and outside the net. It would help the commercial fisherman if the net could be monitored to see if it was towing level, that it was still free from major splits and how full was the codend. Think how that information would help a trawler skipper in his choice of tactics!

Dr. Schärfe (Germany): In some of our tests we used the jellybottle principle which Dr. Carruthers introduced and we found it most convenient for measuring the angle of attack of kites as used in the German herring bottom trawling industry. This helped us to confirm what we had expected — that those kites were often working at a very inefficient angle of attack. We used the jellybottle in its simplest form namely, without compass and other equipment. We had one bottle attached to the board and when the jelly was set you could determine the angles quite easily. They had also experimented with a wireless telemeter in trawl tests because they had had bad experience with cables in the beginning. They found, however, especially with large vessels considerable interference from the sound waves created by the propellers and the engines. Because of that experience he was very interested to learn that other workers had been successful in establishing an acoustic link between the net and the ship and over considerable distances like 1,000 to 2,000 m. He understood this was partly possible by the use of much higher frequencies than they had used. It remained true, however, that with the simple kind of instrument the scope of information you could transmit was limited. Another thing was the question of ruggedness of such instruments. If anything went wrong with the underwater instrument they might get a measurement on which they could not possibly check. That was the great difference of this principle compared with the netzsonde. Through its echo-sounding principle, they knew netzsonde measurements to be correct as long as the recording instrument worked at the right speed. It would be too much to ask a trawler skipper to check up and calibrate repeatedly such a complicated instrument as a wireless telemeter.

Mr. D. L. Alverson (U.S.A.): We had six or eight years experience in using various types of cable which carry a conductor within the towing rope itself. This offers a promising solution if and when the cable producers can provide a suitable cable with sufficient durability. One of the basic problems in using a so-called armoured cable is the flexibility and breakage of the conductors within the cable. We have not been satisfied to date that we have a sufficiently good cable to apply to the heavy work of commercial trawling. It has, however, been very profitable in research as you can convey a number of parameters along those cables. There is some promise along the lines of durability. Because of the great increase in interest in oceanographic research some of the wire companies are actively engaged in investigating the possibility of producing a trawl cable which would carry a number of conductors from which by means of slip rings you could have information from measuring devices on the trawls.

Dr. Cole (U.K.): We have produced a different type of instrument which is quite useful: a small thermograph for recording the bottom temperature which may be attached to the trawl and gives a continuous record of the temperature of the water through which you have towed it. This might be important in the future, inasmuch as the bottom temperature governs the distribution of the fish.

Dr. Schärfe (Germany): Referring to model testing, commented that Mr. Dickson said how research teams should be built up. I think we all agree you need the right people for the right job. You need specialists in this field. We, being biologists interested in techniques, do not try and interfere with engineers. We don't engage in model testing with small-scale models and we try to get the answers to our questions mainly by working with the actual gear. One problem is why does one type of gear catch fish better than another. Among other things this may depend on the shape and behaviour of the trawl net and the shape of the meshes in the net. This is difficult to observe in the full-scale gear.

To secure an answer on that point we therefore intend to carry out tests with models in the scale of 1:4 to see why the two-sided seam midwater trawl is so much inferior to the four-sided seam midwater trawl. These tests will be made in the Baltic in 10 to 15 m depth of water over a sandy bottom and observations will be made by skin divers in the usual way.

Mr. J. A. Tvedt (U.K.): Sixteen years ago we used a kind of measuring device that was connected from the net to the ship much as the netzsonde is. We found however that, when hauling and shooting, the connection was an encumbrance. With the Japanese system you are still using a short length of trailer over the stern and we feel we would rather do without that as well. We feel the fewer things that you have, the better, so I want to see if anybody has a device where a link can be established between the hull and the net without having to use a winch or a cable. There was a case for considering the ship itself as part of the fishing gear. In this connection there was a strong case for building research vessels of two different sizes through which they could investigate the handling characteristics of gear and at the same time those concerned with hydrodynamics could consider the ship as a whole and investigate various means of handling gear on the ship as well as the efficiency of the propulsive devices, steering, etc., as related to the trawls. Naval architects as well as other technicians would find much useful information from such a test. Naval architects were just as keen to know about fish behaviour as the biologists.

Mr. T. V. Hinds (U.K.): In our work at Aden we use an instrument for measuring water depths and temperatures. The instrument is called a Thermistor thermometer. It is contained in a small rugged box which can be used on various sizes of boats like the 20- to 30-footers that we run. The thermostat head is on a strong cable which we can lower to over 100 fm. The thermocline measurement is recorded directly on a recording machine in the boat. This is manually operated and does not require any attention. The instrument gives the actual depth and we can read the actual temperature. Some of our Somali fishermen who are longlining for tuna, after they arrive on the grounds in the morning, discover from this instrument, that the fish are being caught on a pattern at a certain depth say about 30 fm and the word is passed round to the others. This has been very valuable and interesting to us. As a result of it we have found, on the Japanese longlining we are using, that the catch rate has increased from 16 per cent to 90 per cent over a period of four months. An Italian vessel caught 240 yellowfin on 270 hooks. This was through setting the line at the right depth. The Arab fishermen can use this instrument without much trouble. They also use a longline hauler.

Mr. Eldon Nichols (U.S.A.): Dr. Schärfe was quite right in saying that the capabilities of the wire telemeter system applied to trawls are very great compared with the sonic or other systems. Someone should go into the possibilities of developing a system of using a coaxial line for applying to the centre of the trawl wire. This coaxial line would have to have a flexible centre conductor insulated by polyethylene and outer tapes or braid. It would have to be a very tough cable which would stand a lot of use. They would need an array of electronic or vacuum tubes at the bottom. They could do this with solid transducers and transistors and so on. These require very little power which can be furnished by means of batteries at the bottom or the power could be sent down through the centre conductor and filtered out without much difficulty. That is what they did in their transoceanic submarine cables and they had hundreds of these devices on the bottom. They had been there for 10 or 12 years without giving trouble so it was entirely a matter of devoting some ingenuity and development effort to this problem. A good idea of the angle of attack would be got by observing the scratches on the bottom of the shoe of the otter board. Fishermen did this quite regularly. In connection with otter boards there was always a difference between the theoretical and actual performance of any device. He had wondered sometimes at the extreme roughness of the ordinary commercial trawl boards and he thought they might consider the use of 'Fibreglass' with foam plastic interiors. They could get suitable densities and abrasion stresses that were entirely compatible with the use of such boards up to 2,000 fm.

Mr. J. Nicholls (U.K.): I am very interested in the telemetering system. We considered that method in the first place but with the time and money we had available we could not see it being done. I am therefore hoping that in future we will get more details from the Japanese in relation to the paper by Hamuro and Ishii. I was rather surprised to see the accuracies given as one per cent. That is considerably better than one can normally obtain in laboratory machines. As a simple engineer I would like to know how they get those accuracies. They did use the method of interpreting the scratches in relation to the angle of attack and thereby had obtained good co-ordination with other measurements they had made.

Dr. Miyazaki (Japan): The author of the paper is not present and the question is too specialised for me to attempt an answer. After returning to Japan and checking with the author I will answer the question.

Mr. D. L. Alverson (U.S.A.): We have encouraged people to look into the production of the type of cable you have mentioned and studies are going on along those lines. If they could develop a cable of this nature which precludes the need for having a third wire they would have overcome many of the problems facing them. Some of the instrumentation they had used gave them good results. There was an on-bottom indicator which signalled the bridge when the boards were on the bottom. This was important when working along the Continental Shelf. They also took off temperature readings from a depth telemeter unit and they also used a load indicator. This did not correlate out as well as they would like it to do. They were not getting more than 50 or 60 drags out of a cable before they were being plagued with conductor breakages.

Mr. J. O. Traung (F.A.O.): No research is better than its measurements. Speed measurements are especially important for gear research. During the first Gear Congress it was pointed out that fishing gear resistance increased by the square

ONLY with some knowledge of the behaviour of fish in the immediate vicinity or path of the gear can the gear technologist approach objectively the problem of improving the design, rig and/or operation of existing gears or of developing new ones. Relatively few studies have been made of these characteristics of behaviour in exploited fish species, due mainly to difficulties of making underwater observations and measurements in the vicinity of fishing gears, especially in deep water. Recently, however, this type of work has been stimulated by activity in the gear technology field, and by the development of new underwater observation techniques, which have made it possible, for the first time, to obtain detailed information on the orientation, movements and responses of fish in the vicinity of different fishing gears. Developments in the application of echo sounding,[9] of underwater photography and television,[6] of direct observation in shallow water by frogmen and from underwater vehicles[8] and in the production of light meters and other instruments for measuring the stimuli produced by fishing gears and by the fish themselves have been of major significance. At the same time there has been an increase in experimental work in aquaria on the behaviour of fish to different types of known artificial stimuli, with a view to determining their range of perception and responses.[7]

The importance of visual stimuli and vision in the behaviour of fish in their natural environment is well established and has been mentioned for herring.[10] Therefore, as a first step in investigating responses of fish to stimuli produced by fishing gear, the study of visual stimuli seemed appropriate. Such experiments were started in aquarium tanks at the Marine Laboratory, Aberdeen, in 1958, and have been continued in aquaria and at sea since then. Results of studies concerning the reactions of commercially important marine species, especially herring, to both stationary and moving nets and to other types of visual stimuli are presented in this paper. Particular attention is paid to the differences in the responses of the fish to these stimuli in daylight and darkness.

STATIONARY NETS

Daylight experiments

An initial report of these experiments was given by Blaxter, Holliday and Parrish (1958).[3] Aquarium observations were made first in tanks measuring 3·7 m × 1·8 m × 1·1 m on two groups of herring, the fish in one group being about 25 cm long, and in the other about 12 cm long. The herring usually swam in a shoal round the entire tank, but when they were confined to one end and a panel of netting or other barrier placed across the centre of the tank, their behaviour changed. If the netting or barrier presented a strong enough effect, the herring avoided it and circled the half of the tank they were in. Where the barrier was less effective some or all of the herring would swim through. To test the effectiveness of the barriers the number of herring swimming through in a given time was counted.

The following aspects of netting were studied:

(a) Type, colour and thickness of material.

(b) Mesh size, or distance between horizontal or vertical strands where these alone were used. Distances between strands from 2·5 to 30 cm were used. Meshes, when used, were not knotted (to avoid gilling the fish).

Table I—The "effectiveness" of different barriers in daylight.

12 x 20-25 cm herring

Distance between strands cm	Number of fish crossing in 30 minutes: Mesh	Vertical strands only	Horizontal strands only
Trawl twine (white) 0·3 cm dia			
7·5	0	12	5
15·0	8	23	422
22·5	—	600	—
30·0	450	648	420
Cotton driftnet twine (B-black, G-Green, W-white). 0·05 cm dia			
B 3·75	0	—	0
B 7·5	—	0	—
G 3·75	—	—	0
G 7·5	—	103	—
W 3·75	0	—	0
W 5·0	—	148	—
W 7·5	—	344	—
Polyfilament nylon driftnet twine (white). 0·05 cm dia			
3·75	0	9	0
5·0	9	312	0
7·5	0	311	2
Monofilament nylon clear 0·02 cm dia			
7·5	80	—	—
Household cotton white. 0·02 cm dia			
3·75	6	—	—
7·5	14	—	—
15·0	24	—	—
Frame alone	750 crossings in 30 minutes		

17 x 12 cm herring

Polyfilament nylon driftnet twine (white). 0·05 cm dia			
2·5	33	30	114
3·75	183	120	213
5·0	210	78	348
7·5	144	351	387
Frame alone	678 crossings in 30 minutes		

For some results of these experiments see Table I. They all point to the importance of vision in avoiding these barriers. In the first place the reaction distance was ¾-1 m with the thicker more conspicuous materials, whereas with less conspicuous ones it was ½ m or less.

The other main results were:

(a) Effectiveness of barriers was independent of material used, e.g. nylon and cotton driftnet twine of the same colour and diameter were equal in effect.

(b) Thickness of material was very important, e.g. trawl twine with strands 7·5 cm apart was a complete barrier; driftnet twine strands had to be placed 4 cm apart before they became as effective.

(c) Colour was also important. Using different colours of driftnet twine and the same mesh size, it was

apparent that the greater barriers were those colours (black and green) that made the greater contrast with the grey, end walls of the tank. Monofilament nylon was almost completely *ineffective* and herring swam straight into it.

(d) A mesh of netting was usually a more effective barrier than horizontal or vertical strands alone. Results obtained using horizontal or vertical strands alone were quite variable with no evidence for either being more effective.

(e) Effectiveness of barriers depended on the size of the herring. For example, using driftnet twine, a distance of 4 cm between strands was completely effective for herring 25 cm long, but the strands had to be less than 2·5 cm apart to be completely effective for herring 12 cm long.

To test the importance of vision two confirmatory experiments were carried out in daylight. In one a sheet of transparent plastic was placed across the tank. The herring swam "headlong" into it and had apparently no other sense to determine its presence. In the other, a herring was "blinded" by placing opaque plastic over the eyes; it swam into the netting and seemed unable to perceive it. A control fish with transparent plastic over the eyes behaved normally and avoided the netting.

Experiments at low light intensities and in darkness

A further test was to experiment at dusk and in the dark. The group of larger herring (25 cm) were first used and barriers which had proved effective in daylight (driftnet twine of different colours with strands 4 cm apart), were placed across the tank with the fish confined at one end. The tank was covered and the light intensity was gradually reduced. The movements of the herring were observed by taking a sequence of flash photographs at one-minute intervals with an underwater camera or by switching on an artificial light for a few seconds so that an observer could see the herring. As expected, the netting ceased to be an effective barrier, the fish passing through it, when the light reached a certain low value (this was called the "threshold value", measured by an underwater light meter[5]). Fig. 1 shows herring on both sides of the barrier.

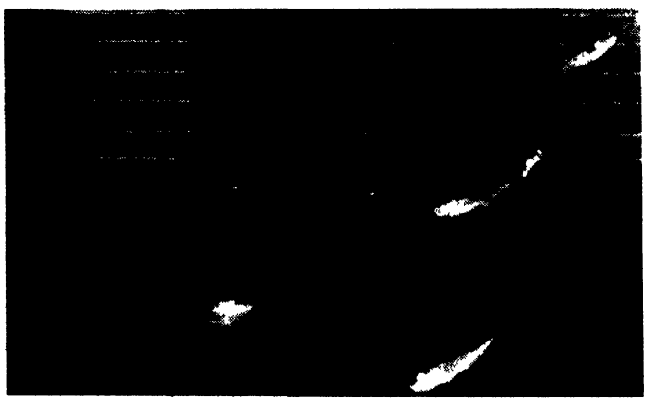

Fig. 1. Herring passing through a stationary net (horizontal strands of white driftnet twine 4 cm apart) in darkness.

In further experiments in a much larger tank measuring 13×7·5×1 m somewhat larger herring (25-30 cm) were used and either black or white driftnet twine barriers (strands 4 cm apart) were placed across the tank against a white or black background. The herring were observed by flashing a light during the dusk-dark period.

For the threshold light intensities (when fish started to pass through the netting) see below. These intensities varied somewhat, depending on the barrier and the background, the herring avoiding the netting for longer as the light intensity dropped (giving a lower threshold) when the netting was more conspicuous, either because it contrasted well with the background or reflected light from above.

Small tank 0·001—0·0001 metre candles.
Large tank 0·01—0·001 metre candles.

The reason for the threshold being lower in the small tank was probably that the fish, being more confined, had a better knowledge of the topography of the tank and netting. They were thus able to avoid the netting at lower light intensities.

As a further test of the possible importance of vision, a curtain of air bubbles was set up across the smaller tank by laying a weighted plastic pipe drilled with small holes across the bottom and pumping air through it. The herring would not pass through this by day but did pass through it in darkness, indicating that the sound or pressure stimuli given off by the air bubbles were less important than the visual ones.

Discussion

Presumably driftnets which are difficult to see, i.e. provide the least barrier effect, will catch the most herring. Thus nets with a high threshold light intensity for avoidance are required and the herring will then start to pass through, or into, them at higher light intensities. Of all the materials used monofilament nylon was definitely most difficult for the herring to see and they swam into it even in daylight. It is of interest that v. Brandt[4] found such nets effective for herring in the Baltic.

Measurements of light intensity at different depths were made on the Scottish east coast driftnet grounds during summer fishing. The values were compared with the threshold found for net avoidance in the large tank (thought to resemble sea conditions best). It was found that the light intensity at the depth of the driftnets was quite high compared with the "threshold" for avoiding nets during a considerable part of the "night". This suggests that capture of herring at these times of year may be relatively inefficient. Of course capture is not only dependent on the light intensity, it may also depend on the luminosity in the water, the number of fish already caught (i.e. net saturation), the angle of approach of the fish, the schooling "pressure", and the activity of fish due perhaps to panic or other factors, as well as the tide.

MOVING NETS

Further experiments were done in daylight and darkness on moving nets, parts of nets and other devices, in large tanks measuring 16 m × 13 m × 2 m. The species used included herring from 25-30 cm long, cod 50-80 cm, whiting 15-35 cm, haddock 30-50 cm and flatfish 15-40 cm. Various numbers were used, but most experiments were done using about 100 herring or 20-30 roundfish or flatfish. After the fish had been established in the tanks the devices mentioned below were pulled through as shown in Fig. 2. Different hauling speeds were used, ranging from 0·25-2·0 m/sec, the usual speed being just under 1 m/sec.

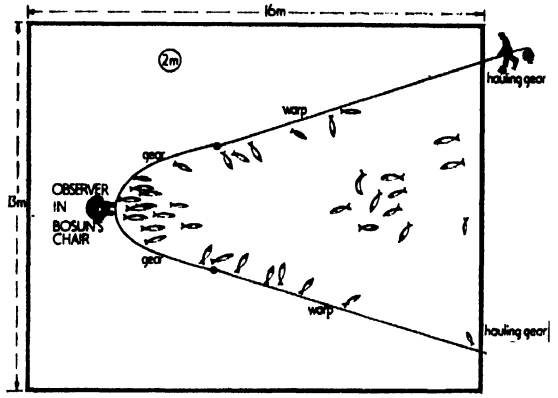

Fig. 2. Diagram showing experimental technique for studying moving nets.

(a) Various types of "groundrope": manila, grass and hemp ropes ranging in diameter from 1-4 cm, with and without bobbins. Trawl twine, polythene tubing, which was nearly invisible, and a bamboo pole (giving a device without a bight) were also used.

(b) Ropes with the following attachments: chain, floats of different colours (12·5 or 22·5 cm dia), underwater lights (40 W, 100 W).

(c) A pierced polythene tube through which air could be pumped, giving a "curtain" of air bubbles.

(d) A rope frame with wooden or wire danlenos, simulating the mouth of a trawl (without the netting). This was used with and without model otter boards and herding devices such as floats on double or single sweeplines.

(e) Panels of netting of different colours ranging in mesh size from 15 cm (6 in) to 120 cm (48 in) and in diameter from 0·1 cm to 0·4 cm.

(f) Model nets

Daylight Experiments

An observer in a moving bosun's chair above the tank noted the reaction distance of the fish, the distance they swam in front and the number of fish passed by the gear (i.e. failed to be herded). A well-defined type of response was revealed by each species. They reacted by turning away from, and swimming in front of, the advancing "groundrope" or other device. The general pattern of reaction was similar to that observed by frogmen of fish in front of trawls and seine nets in shallow water (see films "Trawls in Action", "Fish and the Seine Net").

Table II—Response of different fish to towed devices in daylight.

Experiment	Average range of reaction distance (m)	Average swimming distance (m)	Average % herded*
Herring			
To "Groundropes", etc.	0·3-1·9	0·5-2·0	60-70
To Panels of netting, model nets	0·7-3·3	0·7-2·5 (6·5 shoal)	95-100
Cod			
To "Groundropes", etc.	0-1·2	0-1·6	40-50
To Panels of netting, model nets	0-1·2	0-1·6	90-100
Haddock			
To "Groundropes", etc.	0-1·2	0·3-1·6	45
To Panels of netting, model nets	0-1·2	0·3-1·6	70-80
Whiting			
To "Groundropes", etc.	0·3-1·0	0·3-1·2	20
To Panels of netting, model nets	0·3-1·0	0·3-1·2	75
Flat Fish			
To "Groundropes", etc.	0·3-0·6	0·3-1·0	55
To Panels of netting, model nets	0·3-0·6	0·3-1·0	100

* Herring usually herded the full length of the tank. All the other fish usually herded only a few metres. Here herding means for more than 5 metres.

Results in Table II show:

(i) Reaction distances. When the devices were pulled along the tanks, the fish were herded inwards by the sides (i.e. warps of the model nets) and forwards by the centre, as shown in Fig. 2. The reaction distances ranged up to 3 m, this depending on how conspicuous and how deep the device was, the reaction distance being greater with conspicuous deep devices, e.g. net mouths or panels of netting. The distance was usually about 1 m.

(ii) Reaction to warps. These were usually of 1·5 cm dia rope. The usual reaction distance was 0·5-1 m, the fish swimming inwards at an angle depending on the relationship between the warp and the direction of the haul. The warps were effective in herding in water depths of up to 1 m. Where the water was 1·5 m or more the herding was much reduced.

(iii) Herding by the device. As the fish came under the influence of the device itself in the centre of the tank, they turned away from it (see Fig. 2), and towards the middle of the tow were swimming in front of it. The swimming distance was usually 0·5-1·0 m in front of the device. In the case of herring some fish might be up to 7 m in front, the fish swimming as a school. With some inconspicuous devices the fish were touched by them before being herded.

The percentage of fish herded varied greatly. In general, herring were herded better and for longer than roundfish and flatfish. The roundfish and flatfish were

often herded for a distance of 5 m and then fell back again over the device; the herring were usually herded the length of the tank. It was apparent that percentage herding was greatly increased by conspicuous herding devices, especially those occupying the whole water column. In general netting, even of mesh size up to 120 cm (60 cm × 60 cm), was the best herding device, especially when made of conspicuous material such as 0·4 cm dia white nylon. Air bubble curtains were ineffective as the bubbles streamed back at a high towing speed. Underwater lights were quite effective and tended to give higher reaction distances and swimming distances than other devices. The usual reaction when a fish ceased to be herded was that it was overtaken by the gear passing beneath it.

(iv) Speed of tow. At towing speeds above 1·3 m/sec the device sometimes tended to lift off the bottom. It was apparent though at these speeds that fish of all species were not keeping in front of it. The percentage herding dropped, as shown in Table III. The total number of fish herded also decreased as there was less time for the fish to react to the warps and many were passed by the warps before they could be herded inwards.

Table III—Effect of towing speed on percentage herding.

Towing speed	Average percentage herding (all gears)		
	Cod	Haddock	Herring
Below 1·3 m/sec	38	49	84
Above 1·3 m/sec	31	34	53

(v) Depth. It was obvious that for good herding the device (and also the warps) needed to be at the same depth as the fish (compare "groundropes" alone and nets in Table II). For fish distributed throughout the depth of the tank coarse mesh netting of conspicuous material produced the best herding.

(vi) Differences between species. Herring were most active and were usually herded as a group over the length of the tank, whereas roundfish, and especially flatfish, reacted individually and were more often herded a few metres before "falling back". This depended, however, to a large extent on the device used. Skate and dogfish usually failed to react at all (see Mohr, this Congress).

The results of these daylight experiments confirm the importance of vision in the response of fish to moving devices. In one experiment a number of herring were "blinded" by placing opaque plastic over the eyes; they failed to respond but tended to swim near the surface.

Experiments at low light intensities and in darkness

The same types of experiments were done in the evening through dusk to darkness. Observations were made as before until it became too dark to see the fish. Artificial lights were then flashed during the haul to assess herding, or photographs were taken with a Polaroid-land camera, using electronic flash. In a few experiments observations were also made with a 500 kc/s sector scanning echo sounder.

The experiments showed that the extent of herding gradually decreased as the light intensity dropped. Schooling in herring ceased at about the same time. The reduction in herding appeared in all species and was shown by the reduced reaction and swimming distances, by the low percentage herded (of the total fish in the tank) the disorientation of fish one to another and the low number of fish in the bight of the gear at the end of the haul. It was possible by continuous measurement of the light intensity to estimate the threshold light intensity for herding (taken to be the intensity when herding had dropped to half what it was in full daylight = 50 per cent herded). This value lay usually between 0·5 and 0·05 metre candles. It tended to be lower for roundfish than for herring and was lower with the more conspicuous devices. Photographs of herring and cod reacting to netting and a "groundrope", at light intensities above and below the threshold, are shown in Figs. 3-6. Figure 7 shows a generalised relationship between light intensity and herding. A surprising result was that herding did not take place in darkness when underwater lights were used; despite the importance of vision the underwater lights were ineffective, though they gave the lowest threshold of all. Figs. 8 and 9 show herring reacting to underwater lights by day but not in darkness. It seems that the activity of the fish drops at night and the underwater lights (up to 100 W) are not bright enough to stimulate them.

Experiments at sea

While the importance of vision was demonstrated in all the experiments it was realised that the tank conditions were artificial due to their relatively small size, giving limited space and reflections from the walls. Nor could the other stimuli produced by fishing gear (high and low frequency sounds, damming phenomena) be simulated. The fish had also been caught and therefore might behave abnormally. To obtain further evidence of the importance of vision in herding by gear it was decided to photograph fish in the vicinity of fishing gear at sea in different

Fig. 3 Fig. 4 Fig. 5 Fig. 6

Fig. 3. Cod herded at above threshold light intensity (45 cm mesh net).
Fig. 4. Cod below threshold haul (45 cm mesh net).
Fig. 5. Herring herded at above threshold light intensity (45 cm mesh net).
Fig. 6. Herring below threshold haul (45 cm mesh net).

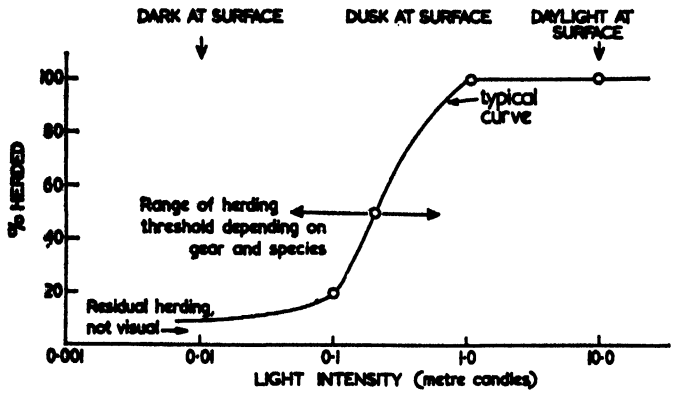

Fig. 7. Generalised graph showing the relationship between light intensity and percentage herding.

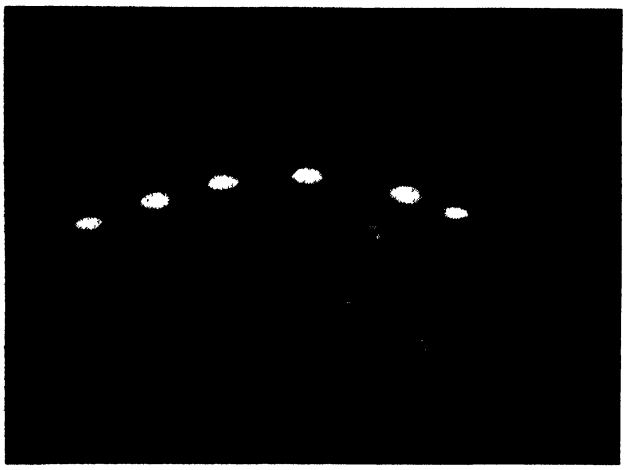

Fig. 8. Herring herded by underwater lights (40 W) in daylight.

Fig. 9. Herring not reacting to underwater lights in darkness.

light conditions. To do this an automatic underwater camera[6] fitted with electronic flash, was attached, pointing downwards, just behind the headline of various trawls, thus giving photographs of fish in the centre of the mouth of the net and in front of the groundrope. An exposure was made each minute throughout a haul.

According to the results of the tank experiments most species of fish would be expected to be oriented and swimming in front of the groundrope in good light conditions and disoriented and poorly herded at low light intensities. The light intensity was therefore measured on the sea bed for each haul.

The results of the analysis of many photographs taken in hauls at different light intensities in different parts of the North Sea tend to confirm the results obtained in the tank experiments. Thus under visual conditions (i.e. at light intensities above the visual threshold measured in tanks) the fish appeared to be oriented with respect to the groundrope and swimming away from it. Below the visual threshold the fish appeared to be less active, and less well oriented, even when in close proximity to the groundrope. Some specimen photographs of herring in front of the groundrope of a trawl are shown in Figs. 10 and 11.

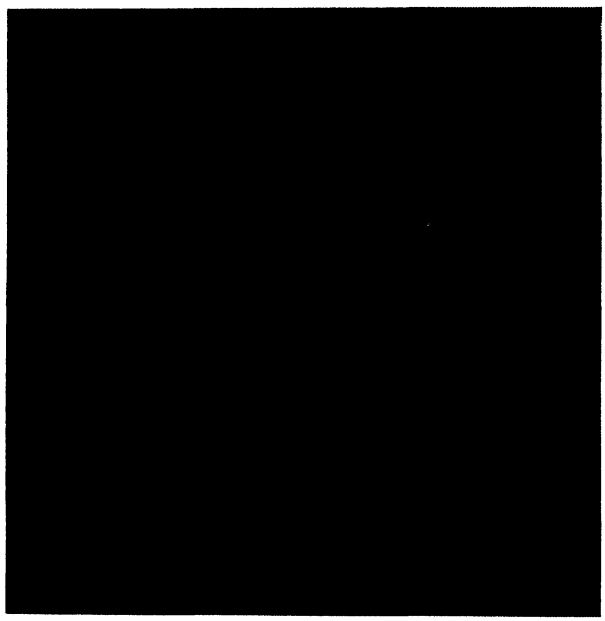

Fig. 10. Herring in front of a trawl groundrope—above threshold.

Discussion

It seems that, under conditions of reasonably good visibility (e.g. in depths up to about 50 fathoms in the open sea under average daylight conditions), fish at the same depth as (within ½-1 m) and in the path of an approaching trawl will react to it at a distance of about 1-2 m. The fish encountering the warps, trawl boards, sweeps or bridles will tend to be herded forwards and inwards towards the path of the net, at an angle depending on the angle the particular part of the gear makes with the direction of tow. The fish encountering the net itself will be herded forward. During this process some fish will "fall back" over the warps, sweeps or bridles and be lost, or over the groundrope and be caught. The rate of "falling back" depends on the nature and conspicuousness of the gear, the speed of tow and the distance already herded. For the species which we have

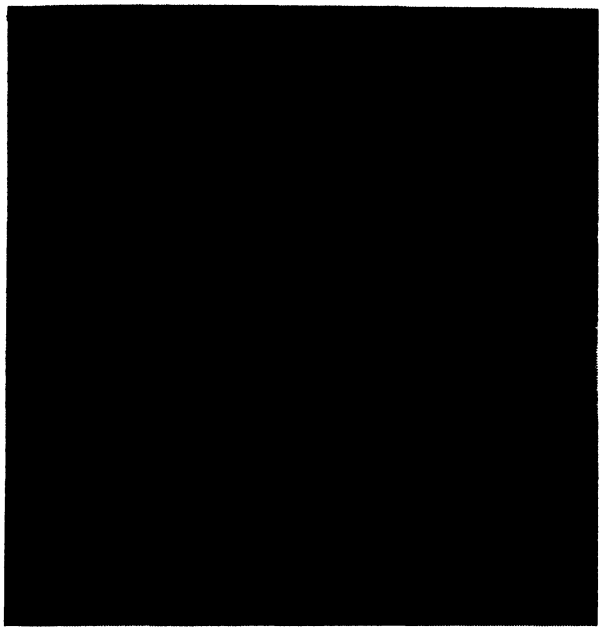

Fig. 11. Herring in front of a trawl groundrope—below threshold.

investigated herding will tend to persist for only a short distance when the towing speed exceeds about 3 knots. Therefore, at the relatively low towing speeds encountered in many demersal trawl fisheries, and under visual conditions, the warps, trawl boards, sweeps and bridles probably play a positive part in the capture mechanism. This is in conformity with experimental results and fishermen's experience, showing an increase in fishing power of trawls with the introduction of the Vignernon-Dahl sweep gear[1]. The results of our experiments also indicate that the efficiency of these components of the gear will probably depend on their conspicuousness and their "depth" (i.e. the vertical distance over which they are effective). Thus, it seems that, for maximum efficiency, warps, sweeps and bridles should be as conspicuous, and have an influence over as great a vertical range, as possible.

These considerations suggest:

(a) That the use of two or three bridles for spreading the net, as now commonly employed with some high-headline trawls, is probably more efficient for herding fish than a single sweep (for a given bridle and sweep angle and towing speed).

(b) The use of paints and other measures to increase the conspicuousness of the bridles might increase their herding efficiency.

(c) Herding efficiency with double or triple bridle gears, might be increased by inserting coarse, large-meshed netting between the bridles, especially near the wing ends of the net, where the distance between the bridles is greatest. However, this will increase the total drag of the gear and introduce additional handling problems.

(d) The production of an air-bubble curtain from the sweeps or bridles would not seem to be an effective measure.

The conspicuousness of the trawl itself may also play an important part in determining the efficiency of capture. As our observations show, fish are herded forward by the mouth of the net so that if it is too conspicuous fish may not be caught because they swim away from it throughout the haul. Reports by Cdr. J. Hodges, during the filming of "Fish and the Seine Net", confirmed that large numbers of fish (principally plaice) avoided capture in this way. In this series of experiments mackerel have been photographed in front of the groundrope and none found in the catch. On the other hand if the netting in the mouth of the trawl is inconspicuous, herding into the centre will be small, and fish might be lost through the large meshes of the wings. Further investigations of the behaviour of fish inside the net (in front of the codend) are needed before the relative importance of visual and other stimuli at this stage of the capture process can be properly judged, but it seems that increasing the conspicuousness of the extremities of the mouth of the trawl (wing ends, bridles, etc.) and reducing it at the centre might be advantageous.

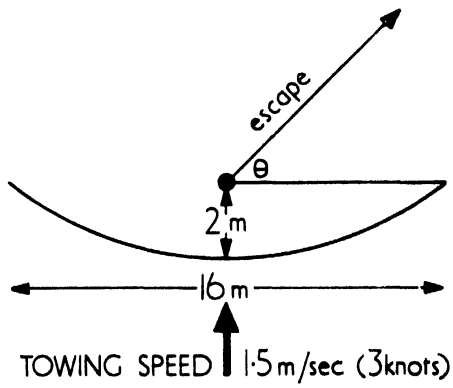

Fig. 12. Diagram showing direction of escape of fish from the centre of the bight of a trawl (see text).

In relation to the herding properties of the net itself and of the consequent loss of fish, it is interesting to consider the chances of escape of a fish and to see how these vary with trawl width and towing speed. A very simplified example will be taken. In Fig. 12 a fish at point ●, in the centre of the path of a net, reacts 2 m from the groundrope of a trawl 16 m wide towed at 1·5 m/sec (3 knots). It swims at an angle θ. It is assumed that a cod 75 cm long can swim at a sustained speed of 2 m/sec for 100 body lengths (75 m) and a herring 30 cm long at 1·75 m/sec for 1,000 body lengths (300 m) before becoming tired (Blaxter and Dickson 1959[2]). It can be shown that the swimming speed required to escape depends on θ and the towing speed, i.e. swimming speed

$$\text{to escape} = \frac{\text{towing speed}}{\text{Sine } \theta} = \frac{1{\cdot}5}{\text{Sine } \theta}.$$

Clearly this must not exceed 2·0 m/sec for the cod and 1·75 m/sec for herring. This means these fish can avoid capture if they swim far enough at the following angles: cod—from 40 to 90°; herring—from 58 to 90°.

However, the swimming endurance must also be considered. If the fish swims at 90°, for example, it will

only escape if it can swim ahead of the trawl up to the end of the haul. The distance swum to escape depends on the width of the trawl and, in the special instance taken with a trawl of 16 m spread, is

$$\frac{8}{\text{Cosine } \theta}.$$

For cod, this distance must not exceed 75 m (100 body lengths) and in the herring must not exceed 300 m (1,000 body lengths). This means that a cod in the centre of the path of a trawl must swim at its maximum sustained speed at an angle θ between 49° and 84° and a herring between 58° and 88° in order to escape before becoming tired.

These may be called the angles of escape. Such angles for trawls of greater dimensions are given in Table IV.

Table IV—Angles between which fish must swim to escape.

Trawl width (metres)	Angles for escape (θ)	
	Cod	Herring
16	49-84°	58-88°
20	49-82°	58-88°
24	49-81°	58-88°
32	49-78°	58-87°

It will be seen that the angles do not change very greatly showing that widening a trawl will not tend to decrease much the chances of escape. If, however, trawling speed is increased—in the case of cod to 2 m/sec (4 knots) or for herring 1·75 m/sec (3½ knots)—no fish at any point within the bight of the groundrope can escape sideways without having to pass through the net. So from the escape point of view increasing trawling speed should be far more effective than increasing trawl width. Other factors are involved, however. The greater area fished by wider nets should be of importance, while increasing speeds of tow may reduce herding. Where herding is an important factor in capture, the speed of tow would need to be adjusted to reduce escapes, but not be so fast that fish had no time to be herded.

So far only the question of increasing the effective fishing width of bottom trawls has been discussed. The question of the advantage of increasing headline height will depend to a large extent on the distribution of fish near the bottom. These experiments suggest that the usual response of fish to bottom trawls is to escape sideways rather than upwards.

In marked contrast to the situation in daylight it would appear that herding by different parts of a trawl becomes much reduced at low light intensities. Some reactions will be caused by tactile stimuli and by pressure disturbances but the effect of the latter, at any rate, will tend to be less directional than visual stimulation. It would seem therefore that the effective "swept area" of a trawl or seine net will be lower at night or in very deep water in daylight where the light intensity would be below threshold.

On the other hand the escape of fish in the path of the net may be lower at night due to lower activity of the fish and of their inability to orientate to the net. It may be that the ineffectiveness of Danish seining at night in some localities may be, in part, due to lack of herding by the ropes. The possibility of increasing the herding power of ropes or warps by night requires consideration. It seems from the experiments that low power lights would not be beneficial.

It is of interest that Bagenal (1958)[1] found that the use of V.-D. sweeps increased catches by day *and* night. He considered this was due to the mechanical stimuli produced by the sweeps affecting fish by day and night. This is not confirmed by the experiments described here, which suggest that the mechanical stimuli provided by sweeps are far less important than the visual ones, which would not be operating at night. Sweeps also change the spread or headline height of the trawl, but clearly, further study is required before these results can be finally evaluated, for V.-D. gear may have an effect unconnected with visual or mechanical herding.

CONCLUSIONS

The results of direct observation in tanks and photography of fish near the mouth of trawls at sea suggest that, of all the types of stimuli produced by stationary and moving fishing gears, the visual ones are the most important in determining the efficiency of fish capture. At light intensities above threshold the fish will tend to avoid stationary nets or be herded by moving ones. At low light intensities the reactions will be minimal.

The implication of these factors in fish capture are discussed with special reference to the herding properties of warps and the relative importance of trawl width and towing speed. It must be emphasised, however, that much remains to be learned of the behaviour of fish in the vicinity of fishing gear. Although in these experiments other types of stimuli have been tested, as well as visual ones (see contribution by Chapman in this Congress), it has not been possible to simulate in tanks the full range of stimuli produced by fishing gear at sea. Further work is required especially to measure the extent of these stimuli and observations of fish in relation to different parts of the gear need to be extended at sea both using cameras and by diving.

Acknowledgements

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Importance of Mechanical Stimuli in Fish Behaviour, Especially to Trawls

Abstract
This paper concerns the sensitivity of fish to mechanical stimuli and the importance of mechanical stimuli in the behaviour of fish. Mechanical disturbances may be conveniently divided into three types: (a) sounds (b) "damming phenomena" which are produced a short distance in front of an object moving through the medium with constant velocity and (c) tactile (touch) stimuli. Sound transmission in sea water 1,500 m/s—almost five times the speed in air could provide a useful early warning system for marine animals. Some marine mammals (whales, porpoises) do employ an echo-location system. Marine fish, in general, however, appear not to have made use of this as they are characterised by relatively poor hearing ability (hear mainly low frequencies —up to 1,000 c/s). The author believes that the dimensions and acoustic properties of the fish head and the very nature of underwater sound within the low range of frequencies to which fish respond would seem to prevent directional hearing based on binaural differences of time, intensity and phase. It seems, however, that the organs of the lateral-line enable a fish to locate moving objects by virtue of the damming phenomena. It seems that complex stimuli such as might be produced by turbulent flow in a net, and very low-frequency vibrations of large displacement amplitude, would stimulate the lateral-line organs. Several hypotheses are drawn by the author concerning mechanical stimuli influencing the behaviour of fish in relation to trawls. The reactions of fish to various mechanical stimuli have been tested in large aquaria. They include sounds from underwater loudspeakers (pure notes and noise), displacements and pressure changes from low frequency vibrations of a trawl warp, rubber diaphragm and a "vibrating door". From these experiments predictions can be made concerning the behaviour of fish towards commercial size trawls. This will enable more reliable interpretations to be formulated from direct field observations on the gear in action and the results of comparative fishing experiments.

L'importance des stimulations mecaniques dans le comportement des poissons, specialement envers le chalut.
Résumé
La communication traite de la sensibilité des poissons envers des stimuli mécaniques et de l'importance des stimuli mécaniques dans le comportement du poisson. Les troubles mécaniques peuvent être divisés en trois types: (a) les sons; (b) les phénomènes de blocage qui sont produits à une courte distance au-devant d'un objet se déplacant dans un milieu à une vitesse constante; (c) les stimuli tactiles. Le son est transmis dans l'eau de mer à une vitesse de 1500 m/sec presque cinq fois plus vite que dans l'air et peut fournir un système d'alarme utilisable pour les animaux marins. Certains mammifères marins (baleine, marsouin) emploient un système de localisation par écho. Par contre, les poissons marins, en général, semblent ne pas avoir utilisé ce phénomène puisqu'ils sont caractérisés par une faible capacité auditive (seulement les basses fréquences jusqu'à 1000 c/sec). L'auteur croit que les dimensions et les propriétés acoustiques de la tête des poissons et la nature même des sons sous-marins, dans les basses fréquences auxquelles les poissons réagissent, semblent leur interdire de situer les sons basés sur des différences bi-auditives de temps, intensité et phase. D'un autre côté il semble que les organes de la ligne latérale permettent à tout poisson de localiser des objects mouvants en vertu du phénomène de blocage; de même les stimuli complexes qui peuvent être produits par le flot turbulent dans un filet et la très basse fréquence des vibrations d'une grande amplitude de déplacement pourront stimuler les organes de la ligne latérale. L'auteur en déduit différentes hypothèses concernant les stimuli mécaniques qui influent sur le comportement du poisson vis à vis du chalut. Les réactions despoissons envers des stimuli mécaniques diverses ont été contrôlées dans de grands aquariums. Ces stimuli comprenaient les sons émis par un haut-parleur sous-marin (notes et bruits purs), déplacements et variations de pression par vibrations de basse fréquence d'une fune de chalut, diaphragme en caoutchouc, et par une "porte vibrante". Ces essais permettent de faire certaines prédictions concernant le comportement du poisson envers les chaluts de dimensions commerciales et permettront de formuler des interprétations plus sûres, à partir d'observations directes de l'engin en action et de résultats d'expériences de pêche comparative.

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Importancia de los estímulos mecánicos en el comportamiento de los peces, particularmente ante los artes de arrastre.
Extracto
Trata esta ponencia de la sensibilidad de los peces ante los estímulos mecánicos y de la importancia de estos estímulos en el comportamiento de aquéllos. Las perturbaciones mecánicas pueden dividirse en tres clases: (a) sonoras, (b) "fenómeno de barrera" que se produce a corta distancia delante de un objeto que se mueve por un medio a velocidad constante y (c) estímulos tangibles. Los sonidos se transmiten por el agua de mar a 1.500 m/seg., que es casi cinco veces más que en el aire, y pueden constituir un valioso sistema de alarma para los animales marinos. Algunos mamíferos marinos (ballenas y marsopas) emplean un sistema de ecolocalización, pero los peces marinos en general no parecen poseerlo y se caracterizan por oír mal (oyen principalmente frecuencias bajas hasta de 1.000 c/s.) El autor cree que las dimensiones y propiedades acústicas de la cabeza del pez y la naturaleza de los sonidos submarinos dentro de gamas de frecuencia muy bajas ante las que reaccionan los peces, parecen impedir la percepción de sonidos dirigidos, debido a diferencias bi-auriculares de tiempo, intensidad y fase. Empero, parece ser que los órganos de la línea lateral permiten a los peces localizar objetos en movimiento por efecto del fenómeno de barrera. También parece ser que estímulos complejos como los que podría producir el flujo turbulento de una red y vibraciones de frecuencia muy bajas y gran amplitud de desplazamiento, estimulan los órganos de la línea lateral. El autor formula varias hipótesis relativas a los estímulos mecánicos que influyen en el comportamiento de los peces con respecto a los artes de arrastre. Las reacciones de los peces a varios estímulos mecánicos se han determinado en acuarios grandes y comprenden sonidos de altavoces submarinos (notas puras y ruidos), desplazamientos y cambios de la presión de vibraciones de baja frecuencia del cable de un arte, un diafragma de caucho y una "puerta vibrante". De estos experimentos se hacen deducciones relativas al comportamiento de los peces ante artes de arrastre de dimensiones normales, que permitirán interpretar con más seguridad las observaciones hechas directamente en la práctica sobre los artes en movimiento y los resultados de los experimentos de pesca comparativa.

VERY little is known of the relative importance of different stimuli in determining the behaviour of fish in the vicinity of trawls. In daylight, vision is undoubtedly important (see paper by Blaxter, Parrish and Dickson in this Congress) but what happens during darkness? The movements of trawls create a variety of mechanical disturbances in the surrounding water to which fish might respond, particularly when vision is restricted.

Mechanical disturbances are produced by the movements of objects in a medium (water) and it is convenient to divide these into three types:

(a) sounds which are propagated waves produced by a vibrating body.

(b) "damming phenomena" (Dijkgraaff 1963) which are produced a short distance in front of an object moving through the medium with constant velocity (Fig. 1) and
(c) tactile (touch) stimuli.

These disturbances stimulate the mechanical sense organs (ear, lateral-line and touch receptors) by producing displacement or deformation of the receptor.

Sound waves

Sound waves are produced by the vibration of an object whose movements are imparted to the surrounding medium as alternate phases of compression and rarefaction in the form of a wave.

The velocity of sound in sea water is approximately 1,500 m/s—almost five times its speed in air and the rate of attenuation of underwater sound is much less than in air. Sound transmission in sea water could therefore provide a useful early warning system for marine animals. The potentialities of such a system have been utilised by some marine mammals (whales, porpoises) which employ an echo-location system.

Marine fish in general appear not to have made use of this and are characterised by:

(a) Relatively poor hearing ability restricted to frequencies below about 1000 c/s.
(b) Relative inability to locate sound sources except at very short range.

The propagation of sound waves is characterised by vibratory displacements of the particles of the medium and rhythmical pressure changes. Due to the low compressibility of water the displacement amplitude is small for a given pressure amplitude with respect to air and since the ear in most marine fish is believed to be a displacement detector this may partially account for the relatively poor hearing in these fish. An auditory mechanism which would detect rhythmical pressure changes would be much more efficient. Such a mechanism requires a compressible component connected to the ear such as a gas filled vesicle. This sort of arrangement is in fact found in some freshwater fish and a few marine fish such as herring.

Hearing in marine fish appears then to be restricted to relatively low frequencies and it is unlikely that fish could detect and react to the high frequencies emitted by echo sounders. It is well known however that some echo pulses are accompanied by an audible "ping" of fairly low frequency to which fish in range might respond.

Directional perception

At the present time there is no evidence that fish are able to detect the direction of a vibrating sound source by means of the ear. At very close range orientation to intense sound sources by means of the skin tactile receptors (v. Frisch and Dijkgraaf 1935) and possibly the lateral-line has been demonstrated (Harris and v. Bergeijk 1962). Under these conditions the stimulus would appear to be large displacements produced by "damming" movements of the vibrating sound source ("near-field effect" (Harris and v. Bergeijk 1962)) rather than the small displacements of the propagated sound wave.

Fish could only detect the direction of sound by comparing it in some way between their two ears, but clearly the dimensions and acoustic properties of the fish head and the very nature of underwater sound within the low range of frequencies to which fish respond would seem to prevent directional hearing based on binaural differences of time, intensity and phase. The lateral-line, on the other hand, presents a different story. It seems that these organs enable a fish to locate moving objects by virtue of the displacements associated with the damming phenomena.

The lateral-line organs

The term "damming phenomena" (Fig. 1) has been used to describe the local pressure changes and water displacements which occur in front of moving objects[1]. These disturbances are not propagated and are detected at short range by the lateral-line organs. Displacements resulting from small objects, are detected at very short range. Large objects will produce larger displacements which will stimulate more of the lateral-line receptors and these objects will be located by the fish at greater distances. It seems that complex stimuli such as might be produced by turbulent flow in a net, and very low frequency vibrations of large displacement amplitude, would stimulate the lateral-line organs.

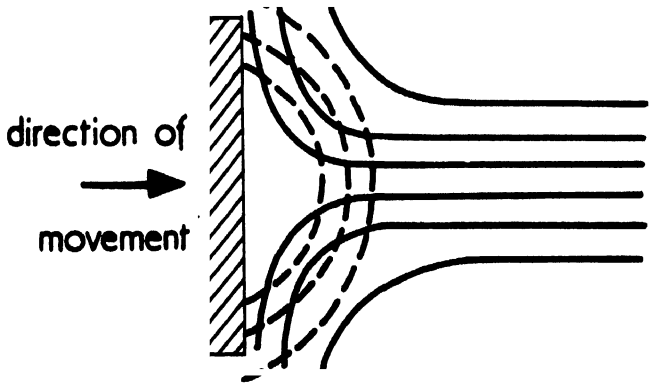

Fig. 1. Damming phenomena in front of a flat moving object showing local pressure increase (broken line) and water displacement (continuous line).

Importance of mechanical stimuli

Marine fish hear and many of them produce sounds of frequencies up to about 1,000 c/s. These sounds are usually produced during social behaviour in relation to territory and breeding. No behaviour in relation to sound depends on localisation of the source except in conjunction with visual and possibly lateral-line stimuli.

"Strange" sounds sometimes induce "fright" responses in schooling fish but the orientation of the school in these reactions is often pre-determined (pelagic herring, for example, will tend to dive into deeper, darker water

when disturbed) and again does not depend on locating the source. These reactions are observed at the commencement of the sound. If the sound continues the fish often appear to get used to it and "normal" behaviour returns. In view of the volume of background noise in the sea it is likely that sounds, more often than not, have no lasting effect on the behaviour of marine fish.

Stimuli to the lateral-line are very important in co-ordinating the behaviour of fish in all its aspects particularly when vision is restricted. Large disturbances usually result in avoidance reactions whereas small displacements give rise to food seeking reactions resulting in an approach towards the source. Although vision is the most important sense involved in schooling behaviour, a limited role may be attributed to the lateral-line organs. For example, individual fish which are disturbed and increase their swimming activity might transmit the "fright" response to the rest of the school through the lateral-line organs.

Fish behaviour in relation to trawls

A few points can be mentioned: There is evidence, mainly from echo sounding, that noises associated with fishing vessels and pelagic nets frighten clupeoids and cause them to dive into deeper water. It is also known from comparative fishing experiments that the use of sweeps increases the catch both in daylight and at night. How far this is due to the herding effect of the sweeps and how far to a change in the shape of the mouth of the net is not known. Any herding effect might be attributed to orientation away from the otter boards and the warps as a result of visual (in daylight) and mechanical stimuli (daylight and at night) produced by them. Possibly the otter boards would have the greater effect as they would undoubtedly be detected at a greater distance than the warps.

A greater difference in the behaviour of fish between daylight and darkness would probably occur in the net. Daylight observations in the mouth of the net have shown that fish are orientated and swimming away from the approaching groundrope. This reaction will not occur at night unless the fish can detect, and react in a directional way to, mechanical disturbances produced by the groundrope or the headline or a damming effect of the net. During darkness it is very probable that fish will pass back into the net more quickly and any orientation away from the net will not be as persistent or accurate as it would be in daylight (Parrish, Blaxter and Dickson 1962).

The onset of escape behaviour will depend on a number of different factors. The method, direction, speed and persistence of escape attempts will obviously vary between species and with physiological condition. The magnitude of the shoaling drive will also be important and variation in this factor will partially account for differences of escape between daylight and darkness. There may also be changes in the general level of activity of the fish.

It has been observed sometimes that escape of fish occurs where the net narrows in front of the codend. Several factors might be operating here. A likely hypothesis is that due to the tapering of the net, the fish are herded closer together thus upsetting the balance of stimuli maintaining the school. There will then be a tendency for the fish to spread out and escape. At night, when the schooling drive is reduced, it is still conceivable that multiple disturbances produced by the swimming movements of the fish, and in addition tactile stimuli, will initiate escape responses in the individual fish. In the absence of any detailed knowledge on the distribution of pressure gradients and turbulent flow in the net, it is also tempting to suppose that in front of the codend the fish are confronted with a resistance ("stow") or zone of high pressure. This is merely speculative, however.

Reactions in aquaria to mechanical stimuli

Experiments to test the reactions of fish to various mechanical stimuli have been started. Stimuli used have included sounds from underwater loudspeakers (pure notes and noise), displacements and pressure changes from low frequency vibrations of a trawl warp, rubber diaphragm and a "vibrating door". In addition, observations on the herding of fish by different towed obstacles at different light intensities were made and the results of some of these are given in the paper presented by Blaxter, Parrish and Dickson at this Congress.

The experiments were done mainly on herring and cod in large tanks measuring approximately 15 m × 13 m in a depth of water between 0·6 and 1·6 m.

Pure notes from an audio-oscillator, ranging from 100 to 15,000 c/s, and recorded noises of various sorts and the noise from a trawl, when introduced into the water through a loudspeaker, did not initiate any consistent reactions in herring or cod. Occasionally cod were observed to turn away from the loudspeaker at the beginning of low frequency sounds.

Reactions of fish to a trawl warp (c 1·25 cm diam) which could be vibrated at different amplitudes and frequencies were observed in different light intensities. The warp which was anchored by a ring on the bottom at one end of the tank, ran obliquely out of the water and was vibrated by an eccentric wheel attachment worked from an electric motor. Frequencies of 2 to 4 c/s were produced with an amplitude of about 1 cm. In daylight the fish appeared to avoid the warp when it was vibrating although the reaction distance was quite small and of the order of 1 m or less. At night, however, the fish appeared to ignore the vibrating warp for the most part although some cod were seen to turn away from it when about 0·5 m away.

Both cod and herring showed a tendency to avoid the area of the tank in which a rubber diaphragm and a wooden "door" were vibrating—both by day *and* by night. These reactions were particularly noticeable with herring although they were spawning fish and relatively sluggish. It is difficult to say exactly what the stimulus was that produced these avoidance reactions. The diaphragm (area 2 sq m) and the door (area 0·3 sq m)

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The use of air-bubble curtains as an aid to fishing

Abstract

The use of air-bubble curtains for guiding herring schools to point of capture was first tried by the U.S. Fish and Wildlife Service in Maine, U.S.A., in the fall of 1957, and has been reported on in the Commercial Fisheries Review of the U.S. Bureau of Commercial Fisheries. The air-bubble curtain was used to intercept the movement of young herring (*Clupea harengus*) and lead them to stationary weirs, traps or seines fencing off a bay. The most satisfactory air-compressing unit consisted of a three-cylinder single-stage compressor, 196 ft³/min at 80 psi, driven by a 52-hp diesel engine. The required power input is about 25-30 hp. The air compressor has a 30-gallon air receiver and a sea water-cooled compressed air aftercooler. To lay out the air curtain, a polyethylene pipe was used. Being flexible, it can be wound on to a reel and minutely small holes can be easily drilled in the wall of the pipe to provide air outlets; furthermore it is inexpensive, lightweight and easy to handle. The disadvantages are that it is buoyant and must be weighted to sink, melts at relatively low temperature so that an aftercooler is required to remove heat of compression from the air. The above compressor could supply air for 2,400 ft of air curtain, emanating from 0·016 inch holes in the pipe, or else 600 ft of a heavier curtain achieved with 0·0312 inch holes, drilled in the plastic pipe at 1-ft intervals. A galvanised wire rope was attached along the pipe to sink it. In commercial fishing trials the air curtain was looped around the school of herring and the pipe was then towed slowly inshore by boats on each end, thus driving the school to within range of the stop-seine. At other times the pipe

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had an amplitude of 2 to 4 cm and at a working frequency of between 1 and 2 c/s large displacements were produced that might be detected by means of the lateral line. Herring did appear to give sudden orientated movements away from the door by day when they swam into what would probably be the zone of greatest influence in front of the door. These reactions occurred at a distance of 3 m from the source. It was not possible to observe such reactions at night.

Conclusions

Mechanical stimuli are important in fish behaviour particularly when vision is restricted and an attempt has been made to see to what extent these stimuli may affect the behaviour of fish towards trawls.

In view of the limitations in the hearing ability of most marine fish, it seems reasonable to attribute a relatively minor role to the detection of sound waves as a way of avoiding capture, although the success of midwater trawling operations for herring and other clupeoids may be influenced by the reactions of these fish to the noise of the ship and the net in some circumstances. Clupeoids probably have a better hearing sense than most marine fish of commercial importance.

Damming phenomena, associated with the movements of the net, and which may cause avoidance reactions in fish could be important in determining their behaviour to the approaching trawl and in bringing about escape once the fish are in the net. Tactile stimuli may also be important in causing escape attempts.

Clearly a great deal of research is needed before a full appraisal of the relative importance of different stimuli in the reactions of fish to trawls can be made. So far very few suitable observations have been made in darkness when mechanical stimuli may be expected to affect the behaviour of the fish. Echo sounding in connection with midwater trawls has given useful information on the behaviour of pelagic species and recently flash photography, by means of a camera attached to the square of a bottom trawl, have shown different patterns of orientation of fish in front of the groundrope between daylight and darkness.[5]

Comparative fishing experiments, although difficult to interpret can give valuable information if carefully planned. Emphasis should be laid on experiments in which the catching efficiency and selectivity of different gears between daylight and darkness are compared. Interpretation of the results of such experiments would be easier if more basic knowledge about the mechanical disturbances associated with trawls was available. Very little is known, for example, about the damming phenomena in front of otter boards or in front of the net. One would also like to know more about the pressure gradients and turbulent water flow within the net and the effect these stimuli may have on the pattern of escape.

A much simpler approach is to observe the behaviour of fish in relation to various mechanical stimuli in large aquaria. This method can give valuable information on reactions to stimuli likely to be produced by trawls. From this, predictions can be made about the behaviour of fish towards real trawls which will enable more reliable interpretations to be formulated from direct field observations on the gear in action and the results of comparative fishing experiments.

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was left idle on the bottom and the compressed air started at ebb tide to stop the retreating herring schools and lead them to a herring weir. The air curtain has also been tried on menhaden which in clear water reacted much the same as the herring, but trials were unsuccessful in turbid waters and in strong currents of 3 knots or more. The air-bubble curtain has proved ineffective as a barrier to sharks. The reaction of herring to the air curtain appears to be primarily a response to visual stimulus. During the 1959 and 1960 seasons 12 units of air curtains gear were assembled for commercial use but the 1961 Maine herring season almost completely failed while during the 1962 season there was a glut and the air curtain was not utilised by the industry, so the future use of this gear on the Maine herring is still subject to question.

L'Utilisation du rideau de bulles d'air comme aide dans la pêche

Résumé

L'emploi du rideau de bulles d'air pour guider les bancs de harengs au point de capture fut expérimenté la première fois par l'U.S. Fish and Wildlife Service, Maine, Etats Unis, en automne 1957 et fut rapporté dans la Commercial Fisheries Review de l'U.S. Bureau of Commercial Fisheries. Le rideau fut utilisé pour intercepter le mouvement des jeunes harengs (*Clupea harengus*) et les guider vers les barrages, trappes ou seines fermant la baie. L'unité de compression d'air la plus efficace consistait en un compresseur à stade unique de trois cylindres, de 5,54 m^3/min à une pression de 5,6 kg/cm^2 actionné par un moteur Diesel de 52 cv. La puissance d'alimentation était de 25 à 30 cv. Le compresseur comportait un collecteur d'air de 113,5 litres et un refroidisseur à l'eau de mer. Pour produire le rideau d'air on a utilisé un tube de polyéthylène, flexible, pouvant être enroulé sur un tambour et dans lequel des trous minuscules ont été percés pour assurer l'évacuation de l'air. Ce tube est léger, facile à manipuler et par cher; il a cependant deux inconvénients: il flotte et on doit l'alourdir pour le faire couler; il fond à des températures relativement basses de sorte qu'un refroidisseur d'air comprimé venant du compresseur est nécessaire. Le compresseur décrit plus haut produisait assez pour 731 m de rideau d'air émanant de trous de 0,3 mm ou bien pour 183 m d'un rideau plus lourd, formé par des trous de 0,79 mm perforés dans le tube à des intervalles de 0,305 m. Pour faire couler le tube, un fil d'acier galvanisé a été attaché tout au long. Dans les essais de pêche commerciale le rideau d'air était normalement mis autour d'un banc de harengs et le tube était alors tiré lentement vers la terre par un bateau de chaque côté de manière à chasser le banc dans la portée de la seine. En d'autres occasions le tube fut installé sur le fond et l'émission d'air comprimé commençait au reflux pour éviter que les bancs de harengs ne se retirent et les guider vers le barrage. Le rideau de bulles d'air a été essayé aussi sur le menhaden qui, dans les eaux claires réagit de la même façon que les harengs mais les essais n'ont pas été satisfaisants dans les eaux troubles et dans les courants de plus de 3 noeuds. Le rideau de bulles d'air était inefficace comme barrière pour les requins. La réaction des harengs envers le rideau de bulles d'air semble être essentiellement une réponse à une stimulation visuelle. Pendant les saisons de 1959 et 1960, 12 unités de rideaux de bulles d'air ont été utilisées commercialement mais en 1961 les harengs étaient presque inexistants tandis qu'en 1962 ils étaient en surabondance ce qui fait que le rideau de bulles d'air n'a pas été utilisé par l'industrie. L'utilisation future de cet engin pour le hareng du Maine est donc toujours en question.

El empleo de cortinas de burbujas de aire como auxiliares de la pesca

Extracto

El empleo de contínas de burbujas para guiar los cardúmenes de arenques al lugar de su captura lo ensayó por primera vez el Servicio de Pesca y Caza de los E.U.A. en Maine en el otoño de 1957 y del experimento se ha dado cuenta en la Commercial Fisheries Review de la Oficina de Pesca Industrial de ese país. La cortina se empleó para interceptar los movimientos de arenques jóvenes (*Clupea harengus*) y dirigirlos hacia estacadas, trampas o redes de cerco que cierran una ensenada. El grupo màs satisfactorio consiste en un compresor de 3 cilindros, 196 $pies^3$/min a 80 lb./$pulg.^2$ movido por un motor diesel de 52 hp. La fuerza motriz necesaria es de 25 a 30 hp. El compresor tiene una botella de aire de 30 gal y un enfriador de aire comprimido refrigerado por agua de mar. Para crear la cortina de burbujas se empleó un tubo depolietileno, que por ser flexible puede arrollarse en un carretel. La descarga de aire se hace por agujeros diminutos perforados en el tubo, el que es barato, ligero y fácil de manipular. Los incon venienties son que flota y hay que lastrarlo para que vaya al fondo; se derrite a temperaturas relativamente bajas y se necesita un enfriador para extraer el calor de la compresión del aire. El compresor citado puede suministrar aire para crear una cortina de 2.400 pies de longitud, con las burbujas saliendo de agujeros de 0,016 pulg o una más espesa de 600 pies con agujeros de 0,0312 pulg hechos a intervalos de un pie. Para hundirlo el tubo se lastra con alambre galvanizado. En los ensayos de pesca industrial con la cortina de aire se rodeó al cardumen de arenque y el tubo se remolcó lentamente hacia tierra por embarcaciones, dirigiendo de esta manera a los peces a la red de parada. En otras ocasiones el tubo se deja en el fondo y se inyecta aire comprimido al comenzar a bajar la marea para parar al arenque que se retira y dirigirlo hacio la estacada. La cortina de burbujas también se ha ensayado con menhaden, que, cuando el agua está clara, reacciona igual que el arenque, pero no se han obtenido resultados positivos en aguas turbias y en corrientes fuertes de 3 nudos o más. La cortina de burbujas ha resultado ser inútil como barrera al paso de los tiburones. La reacción del arenque a las burbujas parece ser principalmente un estímulo visual. Durante las campañas de 1956 y 1960 se emplearon 12 grupos de cortinas de burbujas, pero la campaña de arenque de 1961 en Maine fue un fracaso casi completo en tanto que en 1962 hubo tal abundancia que no se tuvo que recurrir a la cortina, de modo que el empleo futuro de este sistema para la pesca del arenque del Maine es todavía objeto de controversia.

THE use of air curtains for guiding herring schools to points of capture was first tried in the territorial waters of Maine, U.S.A., in the fall of 1957. Positive results of these trials were reported to American fishermen by a series of informal progress reports and finally in Commercial Fisheries Review of the U.S. Bureau of Commercial Fisheries.

In view of the wide interest in the method and its potentialities (some realised and some still unrealised), description of the original trials and a résumé of developments to date is warranted.

Use of this gear grew out of a need to extend Maine sardine fishing activities beyond the limits of depth and distance from shore imposed by the conventional passive methods of fishing with stop seines and weirs. The young two- and three-year-old herring (*Clupea harengus*) that are canned as Maine sardines are taken in stationary weirs or traps and in "stop seines" which are used to "stop off" a cove or section of beach after herring have moved into it.

More active fishing was needed. The herring schools frequently failed to migrate close inshore causing intermittent supply with periodic shortages. Even during periods of shortage, however, schools of small herring were frequently found near weirs and seining sites. (Fig. 1.)

Since herring schools in inshore waters can be led effectively by brush and stake weir leads, it was concluded that a visual barrier of air bubbles might also be effective. (It is necessary to catch and hold the herring in conventional seine gear alive for a period of eight hours or longer to clear their intestines of food before they are transferred to the cannery.)

Fish-guiding trials

The basic units for setting-up an air curtain are (1) a vessel for carrying the gear and personnel to the fishing location, (2) an air-compressing unit, (3) air transport and discharge lines, and (4) a reel or spooling device to wind up and carry the air lines.

Two vessels were used at various times in the Bureau experiments: the 35 ft *Clupea* and the 38 ft *Blueback*.

Both vessels were diesel powered. They were somewhat smaller than typical sardine fishing boats which are generally in the 38 to 50 ft class.

Fig. 1. View of a school of herring "stopped off" with a seine. An empty herring weir is at the right.

The most satisfactory, and most used, air-compressing unit consisted of a three-cylinder single-stage compressor driven by a 52 hp diesel engine. The compressor had an air-volume rating of 196 ft³ of air per minute and a pressure rating of 80 lb per square inch. The required power input for such a machine is approximately 25 to 30 hp. The air-compressing unit also included a 30 gallon air receiver and a sea water-cooled compressed air aftercooler.

The air lines used for carrying and discharge of the air was polyethylene flexible pipe. This material was chosen because (1) it is flexible and can be wound up on to a reel. (2) holes can be easily bored in the wall of the pipe to provide air outlets of a particular size, (3) it is inexpensive, and (4) it is lightweight and easy to handle. Disadvantages of polyethylene pipe are (1) it is buoyant in water and must be weighted to sink it to the bottom, (2) it melts at relatively low temperature (an aftercooler was required to remove the heat of compression from the air before being piped), and (3) very small holes (approximately 0·02 inch and smaller) after being drilled in the pipe will apparently "flow" closed in time.

Air-discharge holes from 0·031 to 0·0135 inch diameter were tried at various times. The larger air holes to produced a heavier, more active air curtain which was most successful. Naturally, more air is required to supply them. Where one 196 ft³ per minute, maximum free-air rated compressor could supply air for 2,400 ft of air curtain emanating from 1/64th inch (0·016 in) holes in the plastic pipe, the same compressor could supply only 600 ft of the heavier curtain achieved with the larger 1/32 inch (0·0312 in) holes. (Fig 2.)

Holes were drilled in the plastic pipe at 1 ft spacings and $^{3}/_{16}$ inch lead wire was wrapped on the pipe (originally to make it sink). It was later found that a galvanised-wire rope attached along the plastic pipe was superior, while it made the entire assembly very strong.

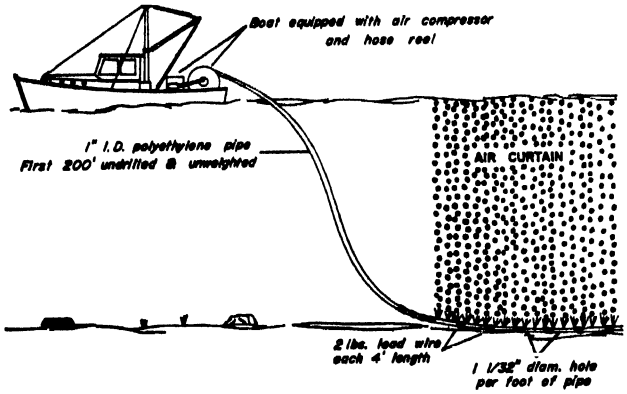

Fig. 2. Diagram of the air-bubble curtain as set from the boat.

Trials on Maine herring

Trials were first attempted in the autumn of 1957 on herring impounded in a rectangular shaped seine "holding pocket". Partial success was indicated when all of the herring were crowded into one-half the pocket before passing through the air discharge. The gear was next tried on schools of herring found migrating through a group of islands in West Penobscot Bay near Rockland, Maine. The first trial indicated that they could be diverted from their migration route. Another showed that, if an air curtain was set up directly in their path, the schools would stop and then run along the curtain parallel to it much as they do when confronted with a seine. (Fig. 3.)

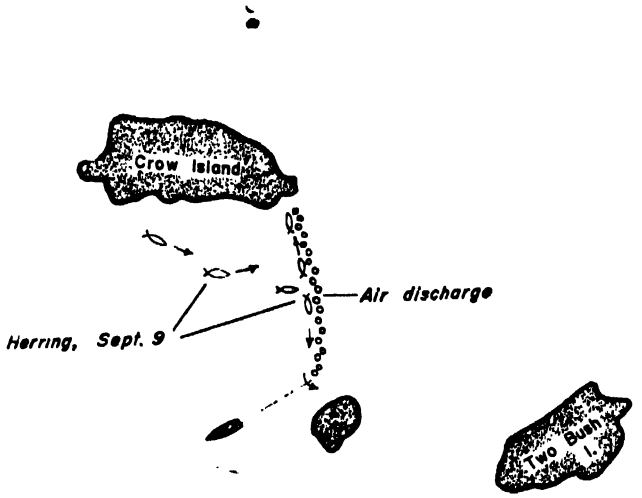

Fig. 3. Initial herring-guiding trials. Herring schools passing between the islands stopped and moved around the air curtain rather than passing through it.

The first commercial fishing trials were made the following season in Casco Bay near Portland, Maine. Herring schools were located moving between Great Diamond Island and Peakes Island each evening. For many days the schools had remained in the centre of the channel beyond the reach of the stop-seine gear.

The air curtain was set up in several different positions, on several occasions, as diagrammed in Fig. 4. Each time that schools were moving down the channel, it was successful in guiding them over the seining sites where they were impounded.

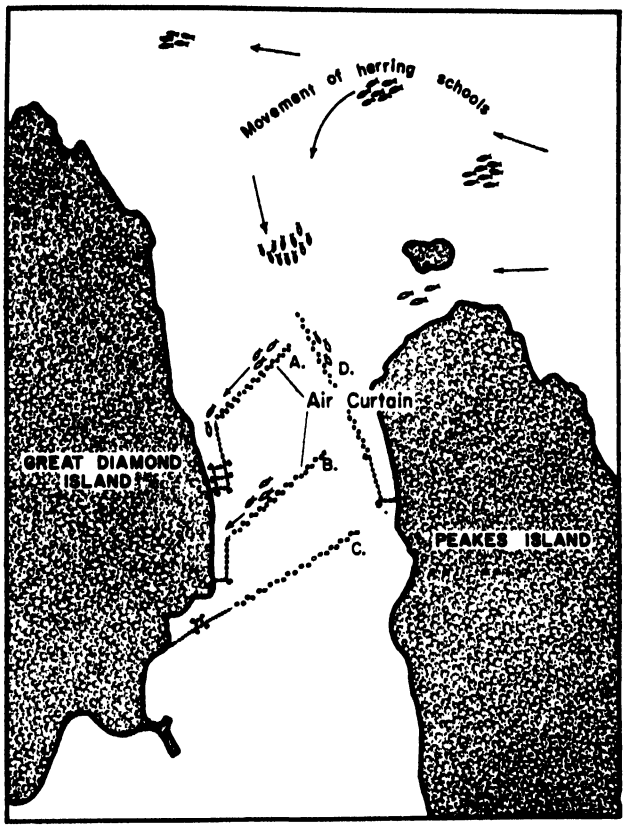

Fig. 4. Diagram of 1958 air-curtain trials in Casco Bay, Maine.

In the seasons following these demonstrations, several sardine fishermen installed air-curtain gear of their own. Figs. 5 and 6 show two applications of one fishermen's air-curtain gear. When herring schools were beyond the reach of the stop-seine twine, an air curtain was used to drive the herring school inshore where it could be impounded. The air curtain was looped around the school of fish (see Fig. 5). The plastic pipe was then towed slowly inshore by boats on each end thus driving the herring school to within range of the stop-seine gear.

The other diagram (Fig. 6) shows the same unit of gear applied as a weir-lead in Cutler Bay, near Lubec, Maine. In this application, the polyethylene pipe was laid on the bottom and left idle until herring schools, moving in on the flood tide, had progressed beyond the weir and the pipe. The air-compressing gear was then started, setting up the air-bubble curtain. At ebb tide, the retreating herring schools encountered the air curtain and were guided along it to the herring wire.

Trials on menhaden

The air curtain has also been tried on menhaden schools, both along the Maine and Delaware shoreline. The

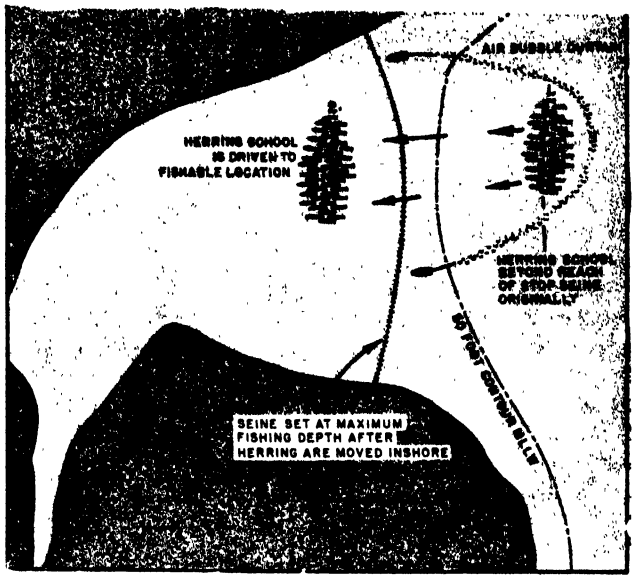

Fig. 5. Method of driving herring schools to fishing site.

findings generally are: in clear water, and in the absence of strong currents, the menhaden react approximately the same as herring. Trials made in the relatively clear waters of Casco Bay, Maine, on large adult menhaden, were effective in guiding and confining the schools. Similar results were obtained in attempts made by a private company in the State of Delaware. These latter trials were successful in holding menhaden schools in clear shallow waters along the shore but unsuccessful in turbid waters inside of Delaware Bay.

Also, strong currents of 3 knots or more, disrupted the curtain and rendered it ineffective.

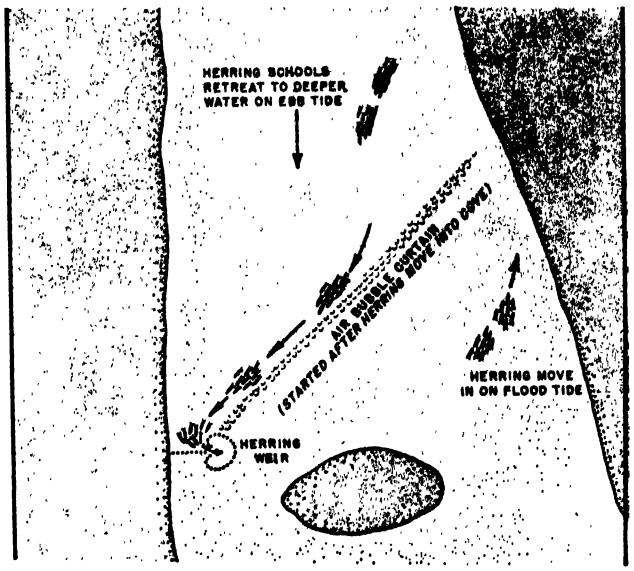

Fig. 6. An air-bubble curtain used as an ultra-long weir lead.

Air curtains v. sharks

Reports of the Bureau's trials led some seaside resort operators to believe that an air-bubble curtain might be

an effective barrier to sharks. Exhaustive tests however, brought the report that "the bubble curtain is ineffective as a barrier to tiger sharks".

Reaction of herring

The reaction of herring to the air curtain appears to be primarily a response to visual stimulus. While some sound and lower frequency pressure oscillations are undoubtedly produced, which may augment the visual stimulus, the similarity of the herring's reaction to that produced by stationary silent objects in the water is quite apparent. The fish follow the line of bubbles just as they follow a line of brush and stakes, rope leads, or seine netting. Although most of the trials were made at the time of evening twilight and continued until after darkness, the rising bubbles could always be seen from the surface; at times the curtain appeared as a bright white sheet due to illumination by disturbed phosphorescent organisms. On other occasions, the residual light from the moon or stars was enough to make the rising bubbles visible; they could, at least, always be seen at the surface. The conclusion that herring react primarily to the visual perception of the air-curtain barrier, therefore, seems best warranted.

Current utilisation in Maine

After trials and demonstrations of the air-curtain gear in 1958 and 1959, several units were assembled and operated commercially during the 1959 and 1960 herring seasons. Approximately twelve units were installed although some of them were quite small, cheaply constructed and of questionable utility. It was anticipated that use of the method might increase with successive seasons (Fig. 7). However, the 1961 Maine herring season was an almost complete failure. The usual inshore runs of herring did not materialise and little fishing activity was carried on. Under these circumstances, air-curtain units were not used to any appreciable extent. During the 1962 season, the opposite situation prevailed and herring were abundant; the schools were caught in great quantities by conventional weirs and seines and no need for additional herring (as could have been made available by air-bubble gear) developed. There was a *glut* of herring and the air curtain was not utilised by the industry.

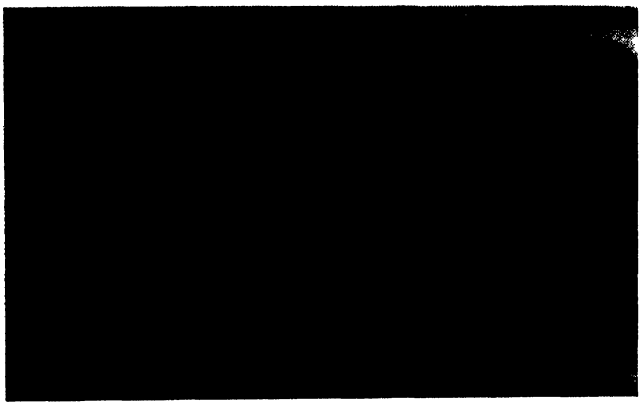

Fig. 7. An air-bubble curtain set in Boothbay Harbour, Maine.

After two years of disuse, the first because of failure of the herring runs and the unavailability of fish in the inshore areas, and the second because of an over-abundance of fish which allowed the conventional gear to catch more than an adequate supply of herring, the future use of the air curtain in the Maine herring is subject to question. However, when another season arrives during which the demand for herring is good and the supply is light, the air-curtain equipment will probably be put into use again.

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Utilisation of Fish Reactions to Electricity in Sea Fishing

Abstract

Electrical fishing with continuous direct current is a well-established technique for freshwater fishing in small brooks or shallow lakes, particularly in Northern Europe. The application of similar techniques in sea fishing would be uneconomic because the much higher conductivity of sea water would require too large and costly power plants. Only after it had been found that pulsed direct current of 20 to 80 impulses per second of about 0·15 millisecond half-value period has the same physiological effect on fish (electrotaxis, electronarcosis), the utilisation of electricity as an adjunct to sea fishing gear could be considered. The author has developed two electrical techniques, one for facilitating menhaden purse seining and one for improving the catching efficiency of trawls. By fitting the anode of a pulsed direct current circuit to the nozzle of the conventional fish pump hose, the fish are strongly attracted to the nozzle and the efficiency of pumping the catch from the bunt of the purse seine on board the carrier vessel is highly improved. This does away with the need of drying up the net and lifting the catch to the same extent as was necessary before, which means a considerable saving of labour and time. Under the attracting influence of the electric field, the fish do not dive down so strongly, Consequently the risk of capsizing the dories and of damage to the net, with loss of fish and gear, when handling large catches is very much reduced. This, together with other rationalisation measures, has made it possible to reduce the crews from 22 to 10 men per boat, and at the same time the fishing power has increased. Since 1958/59 all of the Smith Company menhaden purse seiners have been equipped with this electrical device which requires only the comparatively low peak current of 2,000 to 3,000 amp. Conventional trawls catch only a part (perhaps about 10 to 60 per cent) of the fish in the path of the gear, because the fish avoid the net or escape from it. By having an electrical field of pulsed direct current close in front of the trawl net mouth, all fish in this area can be attracted, stunned and then collected in the net. To this end high voltage pulsed direct current produced on board the trawler is conducted to step-down transformers at the trawlnet through conducters inside the special trawl warps. The stepped-down current is led to four pairs of electrodes distributed around the net mouth between which a practically homogeneous electrical field is built up. By underwater television it was confirmed that this arrangement works according to expectation. By comparative fishing tests the rate of improvement of the catching efficiency was determined to be from 100 to 500 per cent depending on fish species and fishing conditions. Pulsed direct current from 15,000 to 40,000 amp peak current and an impulse half-value period of 1·2 to 1·5 millisec is used according to size and species of fish to be caught. Apart from normal bottom trawling, this technique might also be promising for trawling close over rough bottom (attraction of fish out of shelters) and particularly for midwater trawling.

L'Utilisation des reactions du poisson a L'Électricité dans la pêche Commerciale

Résumé

La pêche à l'électricité—à courant continu—est bien connue, particulièrement dans le Nord de l'Europe, pour la pêche en eau douce, dans les ruisseaux et les lacs peu profonds, mais ces techniques ne pouvaient être appliquées à la pêche maritime à cause de la grande conductibilité de l'eau de mer qui nécessitait des installations électriques trop importantes et trop onéreuses. Ce n'est qu'après avoir constaté que le courant continu pulsé, de 20 à 80 pulsations par seconde et d'une durée, par demipériode d'environ 0,15 milliseconde, avait le même effet psychologique sur le poisson (électrotaxis et électronarcosis) que l'utilisation de l'électricité en mer pût être envisagée. L'auteur a développé deux techniques: l'une pour faciliter la pêche des menhaden au filet tournant et l'autre pour améliorer l'efficacité de capture des chaluts. L'installation de l'anode d'un circuit de courant continu pulsé à l'orifice de la pompe à poissons augmente l'efficacité de celle-ci. Par ailleurs, attirés dans le champ électrique les poissons ne plongent plus avec autant de vigueur et, de ce fait, on évite les risques de chavirement, de dégâts au filet avec perte de poisson et de l'engin—surtout lorsqu'on manipule de grosses captures—et puisqu'il n'est plus nécessaire de lever le filet plein aussi haut qu'auparavant, on réalise en même temps une économie de travail. Cette technique et d'autres mesures de rationalisation ont permis de réduire les équipages de 22 à 10 hommes et d'augmenter les possibilités de pêche. Depuis 1958/59, cet équipement électrique qui n'utilise qu'un courant maximum de 2.000 à 3.000 ampères a été installé sur tous les seineurs de la Cie Smith. Les chaluts traditionnels ne prennent normalement qu'une partie (peut-être 10 à 60%) des poissons se trouvant dans le champ de l'engin parce que ceux-ci peuvent s'évader du filet. Par contre, un courant électrique continu pulsé, situé près de la bouche du chalet, attire et étourdit tous les poissons se trouvant à proximité et les rassemble dans le filet. Dans ce but, un haut voltage produit à bord du bateau est conduit au transformateur -réducteur du chalut par l'intermédiaire de fils conducteurs situés à l'intérieur de fumes spéciales. Quatre pairs d'électrodes réparties autour de l'ouverture du chalut assurent un champ électrique homogène sur toute la bouche du chalut. Des observations sous-marines télévisées ont confirmé que cet équipement donnait les résultats prévus. Des essais de pêche comparative ont montré que l'amélioration de l'efficacité de capture était de 100 à 500% selon les espèces de poisson et les conditions de pêche. Suivant la taille et l'espèce de poisson à capturer, on utilise un courant continu pulsé d'une intensité maximum de 15.000 à 40.000 amperes et d'une durée, par demi-période, de 1,2 à 1,5 milliseconde. Indépendamment du chalutage de fond normal, cette technique peut aussi être développée pour le chalutage sur des fonds accidentés (attraction des poissons hors de leurs refuges) et particulièrement pour le chalutage entre deux eaux.

by

Conradin O. Kreutzer

Smith Research and Development Co., Inc.

Reaccion de los peces a la electricidad y su aprovechamiento en la pesca maritima industrial

Extracto

El empleo de corrientes eléctricas continuas es una técnica bien establecida para pescar en ríos pequeños y lagos someros, particularmente en Europa septentrional. Su aplicación en el mar sería antieconómica porque la conductividad mucho mayor del agua salada exigiría instalaciones eléctricas más potentes y costosas. Hasta que se descubrió que la corriente continua de 20 a 80 impulsos por segundo con semiperíodos de 0.15 milisegs. tiene el mismo efecto fisiológico en los peces (electrotaxia y electronarcosis) no se pudo pensar en aprovechar la electricidad como auxiliar del equipo de pesca marino. El autor ha ideado dos técnicas eléctricas, una para facilitar la pesca al cerco de menhaden y otra para mejorar el rendimiento de los artes de arrastre. Instalando el ánodo de una corriente continua pulsante en el extremo de la manguera de una bomba para peces normal, se ejerce una fuerte atracción y se mejora considerablemente el bombeo de la captura desde el saco del arte de cerco al barco transportador. De este manera se reduce considerablemente la necesidad de secar la red y elevar la captura, con el consiguiente ahorro de mano de obra y tiempo. Bajo el efecto atrayente del campo eléctrico los peces no nadan con tanto vigor por lo que el peligro de que vuelquen los botes o de que se averíen los artes con la pérdida consigiente de peces y material cuando se manipulan capturas grandes disminuye mucho. Esto, junto con otras medidas de racionalización, ha hecho factible reducir las tripulaciones de 22 a 10 hombres por embarcación a la vez que ha aumentado la capacidad de pesca. Desde 1958 todas las embarcaciones de Smith Co. que se dedican a la pesca del menhaden con

redes de cerco han sido dotadas de este dispositivo eléctrico que sólo necesita una corriente máxima de 2.000 a 3.000 amp. Los artes de arrastre normales sólo capturan una parte (quizá del 10 al 60 por ciento) de los peces que encuentran en su camino, porque, éstos los eluden o escapan de ellos. Disponiendo un campo eléctrico de corriente continua de impulses delante de la boca del arte, se pueden atraer todos los peces que haya en sus proximidades, los que quedan aturdidos y entran en la red. Para ello, la corriente continua de impulsos de mucho voltaje producida en el arrastrero pasa a transformadores-reductores en el arte por conductores montados dentro de cables de arrastre especiales. La corriente reducida va a 4 pares de electrodos distribuídos alrededor de la boca del arte, entre los que se crea un campo eléctrico prácticamente homogéneo. Mediante el empleo de la televisión subacuática se confirmó que esta disposición funciona como se esperaba. Mediante ensayos de pesca comparativos se determinó que el rendimiento de pesca mejoraba de 100 a 500% según las especies y las condiciones. Se emplea corriente continua de impulsos con un máximo de 15.000 a 40.000 amps. y un semiperíodo de 1, 2 a 1,5 milisegs. según la talla y especies de peces que se van a pescar. Además de la pesca al arrastre normal en el fondo, esta técnica también podría dar buenos resultados cuando se arrastra cerca de fondos sucios (para obligar a los peces a salir de los refugios) y, en particular, para al arrastre entre dos aguas.

ELECTRICAL fishing in freshwater, which was developed at the beginning of the century, has become established in Central Europe.

If the negative pole (cathode) of a direct current source of about 220 V is grounded or placed in a body of water, and the positive pole (anode), connected to a metal plate about 30 x 30 cm in size (catching electrode), is dipped into the same water body at some distance from the cathode, the fish in the immediate vicinity will swim towards the anode in a very short time. Shortly before reaching the electrode, most fish stop swimming, turn over and go into a state of narcosis. They can then easily be taken from the water with a dip-net.

Physiologists have determined that the voltage over the fish body, between head and tail, causes three reactions, i.e. attraction (electrotaxis), stunning (electronarcosis) and electrocution, and that the required voltage differs according to the species.

Since in a given electrical field the voltage over large fish is greater than over small fish, large fish of the same species will be more affected; electrical fishing is therefore selective.

The effective range of the electric field is, however, rather small. As can be seen from the following formula, the effective range increases, with the square of the current and the power requirements even with the fourth power.

$$= \sqrt{\frac{L \quad r}{G \quad 2 \quad \pi}}$$

R — effective range in metres
J — current supplied by the electrode into the water
L — length of fish
r — specific conductivity of water in ohm × metre
G — body voltage of the fish species

Note : In the above formula the factor 2 is for surface operation and increases up to 4 when the electrode is submerged deeper.

Increase of effective range is therefore practically limited, and commercial electrical fishing in freshwater remains most effective in small or shallow waters like brooks or certain lakes.

In view of the limitations of electrical fishing there appeared to be little promise in applying the technique to sea fishing as the high conductivity of sea water presents additional serious difficulties. A current of 10 amp, which would be sufficient in freshwater, would for the same efficient range have to be increased to about 10,000 amp in sea water. This indicated that continuous direct current in sea water would be uneconomical, but a solution to this problem was found when it was discovered that fish have the same reactions to pulsed direct current as they do to continuous direct current, provided that the shape, duration and rate of the impulses is suitable. Turning on the electric field for only a short time and then turning it off for a relatively longer period has an effect similar to that in motion pictures, where the eye gets the impression that the screen is continuously lighted. Tank experiments have shown that from 20 to 80 impulses per sec are sufficient. The half-value periods of these impulses need to be only of the order of 0/15 milliseconds and for technical reasons are produced in practice by condenser discharges. The exact relation between the maximum voltage and the half-value period required are given for instance by Muralt[2] (1945). For physical reasons electrical fishing in sea water must be done with currents having impulses of longer duration.

In sea fishing the simple method of electrode and dip-net cannot be applied, but electrotaxis and electronarcosis can be utilised in certain cases as a valuable auxiliary means for improving purse seining and trawling.

This paper describes a method of using electricity for simplifying and improving the discharge of big quantities of fish from purse seines, and a method of electrically attracting and stunning fish as an adjunct to trawling. Both methods have been developed over the past six years by the Smith Research and Development Company in Lewes, Delaware, U.S.A. The first method was introduced five years ago and is operated with good results on 80 purse seiners. The second method is about three years old and has so far been tested on several research vessels and is now in use on a commercial trawler, while equipping of other trawlers is planned.

Menhaden purse seining

On the east coast of U.S.A., menhaden is fished by purse seining with two dories which set and close the net around the fish schools (Fig. 1). When the seine is pursed, the net is hauled and the fish concentrated in the bunt—about 30 fathoms deep and 30 fathoms in diameter. The fish are then pumped into the carrier boat. Efficient pumping is only possible if the fish are so concentrated or "dried up" that the nozzlehead is continuously surrounded by fish. They can only be pumped if crowded so densely that they cannot escape the suction of the pump.

Good sets may result in the catch of 100,000 to 300,000 fish of 300 g each. Lifting such large catches by hand-hauling is extremely difficult and drying up can be dangerous as the fish tend to dive. The pump hose and pump intake have an internal diameter from 25 to 40 cm and can pump from 7,000 to 18,000 fish per minute. It occasionally happens that the weight of the fish overcomes the buoyance of the floats or the breaking strength

of the nets so that the nets are torn and the catch lost. Sometimes the sets are too large to lift and the nets have to be cut and the fish released.

Fig. 1. Aerial view of the operation of a menhaden purse seine with two dories. The inner ring is the floatline, the outer ring the fish which push the netting outwards in their attempt to escape.

Electricity has been introduced to strengthen this weak link of menhaden purse seining. The nozzle of the pump hose was fitted with the anode of an electrical power source producing pulsed direct current. The cathode is placed in the water but at some distance from the nozzle. When the fish are concentrated in the bunt of the seine and the electricity is switched on, they are electrically attracted to the nozzle so that the pump continuously works at full capacity. In this way the bunt does not have to be lifted ("dried-up") against the weight of the fish trying to go down, at the risk of capsizing the dories, and the danger of damage to the net is considerably decreased. The fish actually form a dense spherical concentration of about 4 to 6 ft dia round the anode at the nozzle and this concentration is under such a strong attracting force that it moves up and down with the nozzle when the carrier boat rolls in the sea. Part of the fish may even be lifted out of the water (Fig. 2). After this dense concentration has formed, the peak electric field around the nozzle decreases as there is a lower current flow due to the lower conductivity of the fish compared with that of the sea water, and less fish are attracted from a distance. When most of the fish from the concentration are pumped off, the electric field increases in strength again and more fish are attracted so that a balance is established between fish attracted and those pumped away, which gives continuous and efficient pumping.

With this electrical technique, it is no longer necessary to lift the bunt by hand or mechanically to concentrate the fish for brailing. With large catches this brailing may easily take more than an hour. The pump nozzle is simply lowered and forms its own concentration, this means a considerable saving of time.

For this practical application of electrotaxis a rather low current of 2,000 to 3,000 amp is sufficient. The electric field is made just sufficiently strong to attract the fish but not high enough for electronarcosis, in which case the fish would sink out of suction range. The current needed is adjusted according to the actual size of the fish.

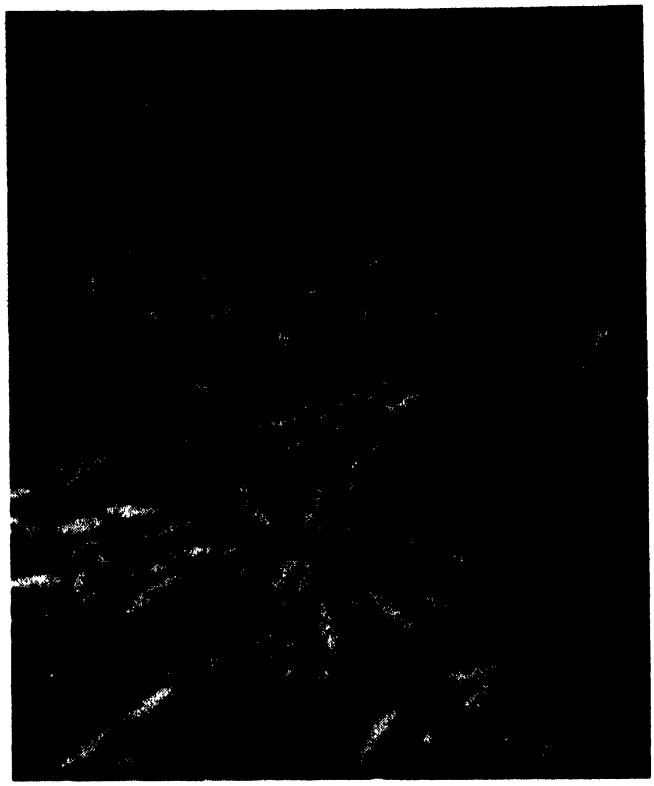

Fig. 2. Menhaden being attracted to the electrified nozzle of the pump hose. The nozzle is near the surface so that some of the fish are actually being lifted above the surface by the fish from below.

Schools of commercial fish are often accompanied or chased by large predatory fish which thus also get in the purse seine. When using the conventional pumping method without electricity, these large fish (mainly shark) often block the hose on the pump, causing considerable inconvenience and loss of time. Due to their greater length, these fish take a much higher voltage when they enter the electrical field around the anode at the nozzle. They are consequently stunned and sink down out of the suction range so that there is no blocking of the pump.

This type of electrified pumping equipment was installed during the years 1958 and 1959 on all menhaden purse seiners operated by the Smith Company off the U.S. east coast. It has been responsible, together with other improvements, for a more rational use of labour on board and has resulted in a reduction in crew members from 22 to 10, while at the same time the catching efficiency per boat has increased due to the gain in fishing time and the avoidance of catch losses.

Trawling experiments

Even with modern trawling techniques using echo sounding, there is no guarantee that all fish detected or available in the path of the trawl gear will really be caught. This is because fish may be frightened by the trawl gear

to such an extent that they either avoid the gear completely or escape through large meshes in the front part of the net. The estimates of fishery experts regarding the percentage of fish actually caught from that available, varies widely between about 10 and 60 per cent. There are reports of midwater trawling trials with underwater television in which an estimated 30,000 baskets of fish entered through the net mouth but only four baskets were found in the codend.

In recent years underwater television has increasingly been utilised for observing the reaction of fish towards fishing gear. Similarly, as was done by other researchers before, the author has also used underwater television in connection with trawls (Fig. 3). To allow these observations to be conducted without artificial light they had to be made in about 30 m water depth. Unfortunately on these grounds only few fish were available. The conditions were therefore not the same as in commercial trawling which is done in depths ranging from about 60 to 600 m. Nevertheless, the results give some indication regarding the reactions of fish which may also be valid for greater depths. It was found that the fish always swam in the towing direction some metres ahead of the net, adjusting their swimming speed to the towing speed. They always seemed to keep a certain distance from the net which may be in relation to their swimming capacity. Only very rarely could fish be seen entering the net and sometimes it was further observed that fish, which had entered the net, would leave again through the net mouth. After some time of swimming in the towing direction in front of the net, the fish normally move over to one side and then let the net pass.

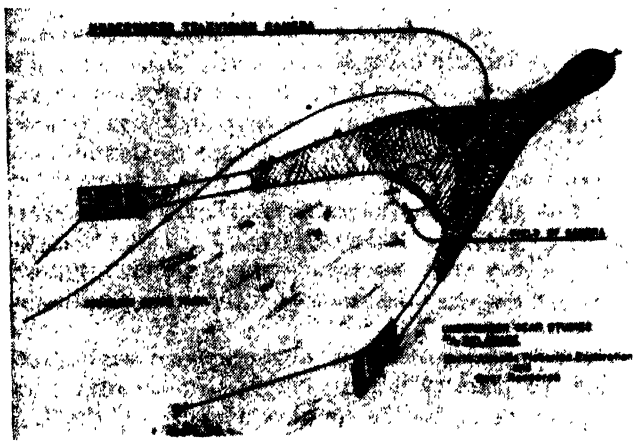

Fig. 3. Schematic view of a conventional otter trawl equipped with underwater television for the observation of the behaviour of fish towards the net.

Commercial trawling depends therefore on fish which are almost incidentally caught. Although catches have been increased by introducing bigger and more powerful trawlers with improved echo sounders, nets and winches, this situation has not been changed basically.

These observations indicate that there is a possibility of utilising the known effects of electricity on fish. Since the fish seem to keep in a rather small zone in front of the net, it was suggested that, even with an electric field covering only about the height and the width of the net opening, it should already be possible to increase the catching efficiency very considerably. By anodes attached to the net, the fish would first be attracted into the net and then stunned to preclude further escape. Even if they should recover in the bag of the net and try to swim out through the net mouth, they would again meet the "electric wall" which thus acts as a valve letting the fish pass only in one direction, i.e. into the net.

The instrumentation for this mode of applying electricity as an adjunct to trawling was developed step by step and throughly tested in practical fishing. Underwater television was used for finding the most suitable position for the electrodes and to observe the effect of electricity on the fish. It could thus be confirmed that, with the electricity switched on, no more fish could be seen swimming ahead of the net. Instead, stunned fish could be observed suspended upside-down in the water; after having passed by the camera, they were collected in the trawlnet.

In order to accurately determine the advantage of this electrical technique, comparative fishing trials were conducted using the same trawlnet alternatively with and without current. Since in conventional bottom trawling on one and the same ground, catches may also vary widely, a great number of comparative tows have to be made to secure statistical significance. These tests which must also be made in such a way that external conditions such as time of day, current, weather, etc. are as uniform as possible for each pair of alternative tows, should also be extended to commercial fishing grounds and greater depths.

To achieve some statistical evaluation, 170 test tows were made, alternately with electrified and non-electrified trawls. The tows were deliberately short so catches could be kept small enough for convenient counting, and so that the shorter interval between electrified and non-electrified tows would minimise variations in general conditions.

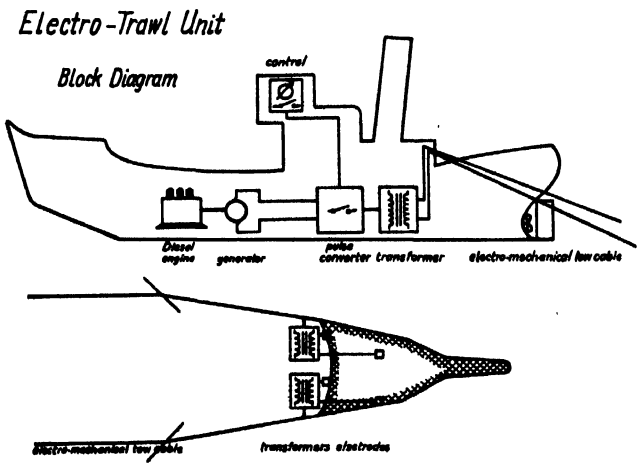

Fig. 4. Block diagram of the electrical equipment used in the trials to improve the catching efficiency of trawl gear.

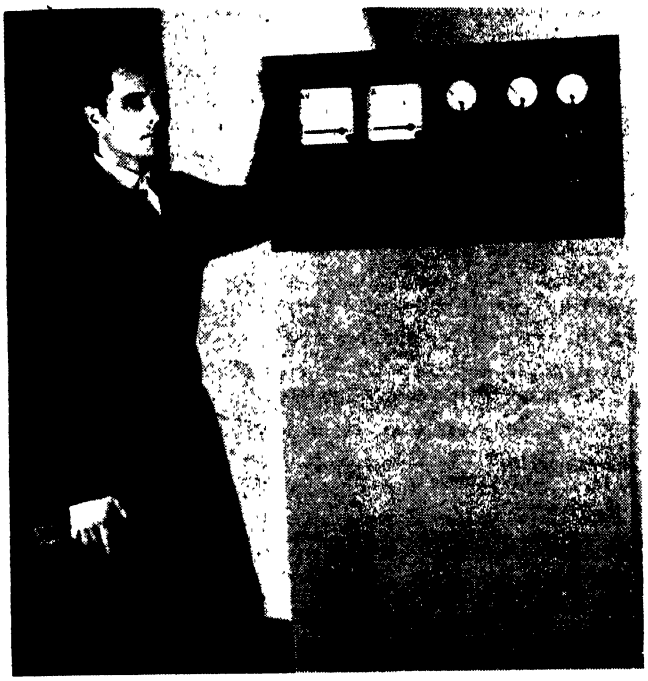

Fig. 5. The electronic convertor which transforms the continuous DC into pulsed DC of the desired characteristics.

Fig. 4 shows the arrangement of the equipment schematically. A diesel-driven electric generator on board, the trawler produces the electrical power which in the electronic converter (Fig. 5) is converted into impulses, i.e. pulsed direct current. By means of a small control board (Fig. 6) the skipper is able to vary the power output and the impulse rate per sec within a wide range. By means of a transformer the impulse voltage is stepped up to high voltage which is conducted through a concentric conductor in the warp (Fig. 7) to the net which may be at a distance of up to 2,000 m. By underwater impulse transformers attached to the net (Fig. 8) the voltage is again stepped down to the level of low voltage and high current suitable for fishing purposes.

To obtain an electric field as homogeneous as possible over the whole area of the net opening, four pairs of electrodes were distributed around the net mouth. Furthermore, the primary coils of the step-down transformers were connected in series to have almost equal current flowing between each of the four pairs of electrodes. The peak current in water was varied between 15,000 and 40,000 amp according to the size of the fish to be caught. The half-value time of the impulse was chosen between 1/2 and 1/5 millisec. This is about ten times the value found necessary for fish reaction in the tank tests mentioned above. This longer impulse period is needed because, due to the propagation conditions of electrical current of such high frequency in sea water, the current would otherwise concentrate around the cables connecting the two electrodes with the step-down transformer rather than build up a field in the water between the two electrodes.

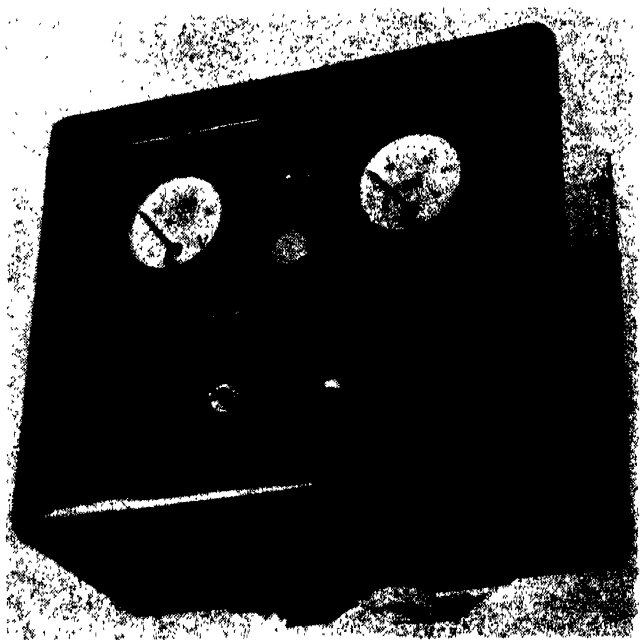

Fig. 6. The control board by which the output and the impulse repetition rate can be carried over a wide range according to the size and species of the fish to be caught.

Part of the catching results obtained in a series of 82 comparative tows in 60 to 100 m depth off the east coast of the U.S.A. are shown in Fig. 9. Out of the great number of species caught, the figure shows the catch results for one typical flatfish species, grey sole, and one typical roundfish species, whiting Am. The increase in catches when applying electricity was of a similar range for the other fish species.

The results show that the increase in catch was larger for the roundfish which, because of their better swimming capacity, can escape the net more easily when there is no electric field. The difference was not so pronounced for flatfish which are poor swimmers. In the few cases when larger quantities of fish were available, the difference

Fig. 7. The special trawl warp with insulated conductor core for transferring the impulse current from the trawler to the trawlnet.

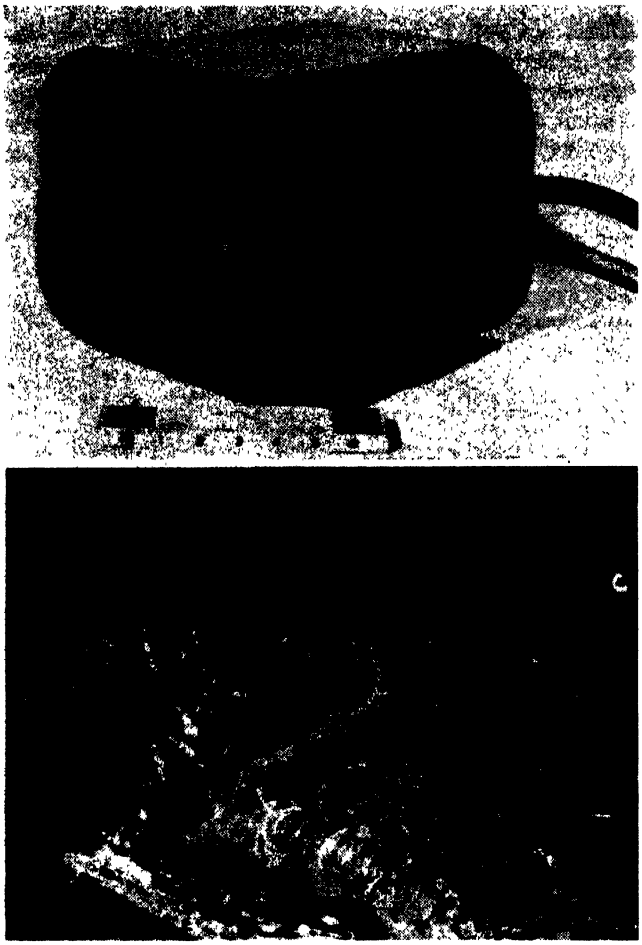

Fig. 8. The underwater step-down transformer (above) which is attached to the groundropes of the trawl net (below).

between electrified and non-electrified tows was particularly pronounced.

On average the rate of improvement of the catch efficiency by means of this electrical device was between 100 and 500 per cent, depending on fish species and fishing conditions. The graphs in Fig. 10 show the amount of catch by the number of fish taken but fail to show another advantage of the electrified trawl, namely, its selectivity. It was found that the catches made with the electrified gear were always composed of larger fish than the normal catches. This is, of course, due to the fact that larger fish are more affected by a given electric field strength than smaller fish. Apart from the voltage, the selectivity of electric fishing can be improved by choosing the optimal impulse output and impulse repetition rate for the desired size and species of fish. Much more experimentation will however be required before these valuable possibilities offered by electrification of trawls can be utilised to full advantage and further.

Discussion

Since the electric trawl showed its greatest catching superiority when large schools were encountered, one possible theory is that most fish not only try to avoid the net mouth but also try to avoid being crowded by their own or other species. Thus, with this double reaction towards avoiding the net, the conventional trawl would be at a disadvantage but electrification would prevent the escape.

The catch increases for the electric nets do not show the further advantage that the electric net always caught more of the larger fish which have higher market value. The catch of larger fish concurs with freshwater electrical fishing results which indicate that larger fish are especially responsive to electric attraction.

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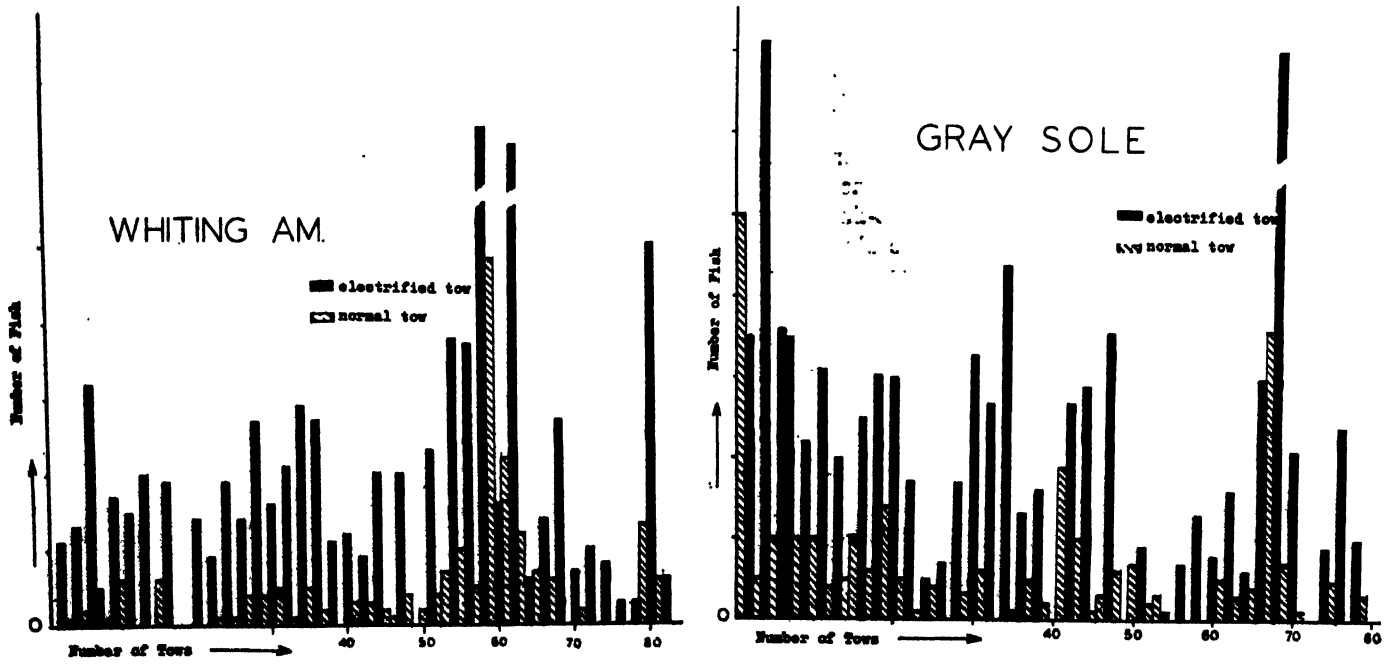

Fig. 9. Graphical presentation of the comparative trawl catches, obtained without (hashed) and with (black) electric current, of whiting and grey sole.

Problems of Electro-Fishing and Their Solution

Abstract

The paper starts with a brief outline of the physical and physiological theory of electric fishing, then goes on to describe the equipment installed in 120-ft seiner. The electrical plant is powered by a 100-kw generator and the anode of the electrode system is formed round the end of a hose connected to a fish pump. The hose is sufficiently long to pump from 150 ft. Underwater lights are also used. The correct choice of the various ranges of the equipment is discussed. The visual effect of the pump hose, the suction effect and the electric field all have ranges at which the fish are scared away. The underwater lights and the electric field also have ranges over which they are effective in attracting the fish within the suction range of the pump. Lastly there is the electrical stunning range which must be less than the suction range. The paper is well illustrated with echograms showing the effect of lowering the equipment into fish traces. From one of these traces 12 tons of herring were pumped during trials on Newfoundland grounds in December 1958. The damage to the fish coming through the pump is given as less than 3 per cent.

Problemes de la pêche électrique et leurs solutions

Résumé

La communication contient une description générale des théories physiques et physiologiques de la pêche électrique et décrit l'équipement installé sur un senneur de 37 m. L'ensemble électrique est alimenté par un générateur de 100 kw et l'électrode de l'anode est placée autour de l'orifice du boyau de la pompe à poissons. Le boyau est d'une longueur suffisante pour pomper d'une distance de 45 m. Des lampes sous-marines sont aussi utilisées. L'étude traite du choix correct des différentes portées de l'equipement et il est signalé que l'effet visuel du boyau, l'effet de la succion et la champ électrique ont tous des portées qui effraient les poissons. Les lampes sous-marines, le champ électrique ont des portées efficaces pour l'attraction du poisson dans le champ de succion de la pompe. Enfin, le champ électrique peut assommer le poisson mais la portée de cet effet ne doit pas être inférieure à celle de la succion. La communication est abondamment illustrée avec des échogrammes signalant l'emplacement de l'équipement dans la couche d'eau, en même temps que les traces de poissons. D'après un de ces échogrammes, 12 tonnes de harengs ont été pompées pendant les essais de pêche sur les fonds de Terre-Neuve, en décembre 1958. Moins de 3% des poissons ont été endommagés en passant par la pompe.

Problemas de la electropesca y sus soluciones

Extracto

Comienza la comunicación con un breve bosquejo de la teoría física y fisiológica de la electropesca y pasa a describir el equipo instalado en un barco para le pesca al cerco, de 120 pies de eslora. La instalación eléctrica cuenta con un generador de 100 kw. El ánodo del sistema de electrodos se forma alrededor del extremo de la manguera de la bomba que eleva el pescado. La longitud de la manguera es de 150 pies. Se emplean luces submarinas. Se discute la selección exacta de los diversos alcances del material. Los efectos visual y de succión de la manguera y del campo eléctrico tienen límites traspasados los cuales los peces se asustan y huyen. Las luces submarinas tienen también un alcance dentro del cual atraen a los peces al sector de succión de la bomba. Finalmente, hay un alcance de aturdimiento que tiene que ser inferior al de la succión. La ponencia está bien ilustrada con ecogramas que muestran el efecto de arriar el material hasta que llega a los trazos de los peces. De uno de estos trazos se elevaron 12 tons de arenque durante los ensayos de diciembre de 1958 en los bancos de Terranova. Sufre daños menos del 3% de los peces que pasan por la bomba.

by
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THIS is a brief outline of the physical and physiological theory of electro-fishing:

When fish are influenced by direct current or pulsed DC electric fields, three reactions can be observed at certain values of field strength :

(a) *The first reaction.* This is caused by weak electric fields. It is indicated by the fish jerking slightly and moving out of the field.

(b) *Electrotaxis.* This occurs in strong electric fields of direct current or of pulsed direct current. The fish turns its head towards the anode (positive electrode) and swims straight to it.

(c) *Electronarcosis.* This occurs in very strong fields. The fish becomes unable to move, either due to narcosis or even to electrocution.

continued from page 550

Since the electrode pairs were evenly spaced over the net mouth, a homogeneous field resulted in the area in which the fish accumulate. The term "homogeneous" is not used in its strict physical sense but indicates that the field varies only within the limits of optimum voltage to affect certain sizes and species.

There is no quantitative proof that sizes or species can be selected by electrical fishing but sufficient staff was not available in these experiments to record and analyse these factors. This will be done in future. It was obvious that larger fish were taken in greater quantity by electrification and, to a certain degree, there seems reason to believe that selection can be made for both size and species. Traditional methods permit only one practical method of size selection, i.e. through net mesh size. The electrical method influences fish *over* a certain size, since with the right pulse rate per sec, fish under a certain size are not as greatly influenced. The fact that different species gather at different distances from the net gives a further possibility of species selection through adjustment to the extension of the electrical field.

The electrical method is not limited to the bottom-trawl industry. In experiments over rocky grounds where normal bottom trawls could not be used, electrodes operated off the bottom, drew the fish from the rocks up into the area where net operation is possible. Future research will concentrate on midwater trawling.

References

[1] Rüdenberg, R. Elektrische Schaltvorgänge, Springer Verlag, Berlin. 1953.

[2] v. Muralt, A. Die Signalübermittlung im Nerven, Verlag Birkhäuser, Basel. 1945.

For electro-fishing procedures in general, electrotaxis is of most importance.

The value of the field strength at which these three reactions occur is determined by the corresponding body voltage. The voltage drop of the fish from mouth to tail in an electric field is dependent on the following factors :

(a) Strength of field in the surrounding water.
(b) Length of fish.
(c) Relation of specific resistance of the fish body to specific resistance of the water surrounding the fish.

A large fish of a certain species picks up a higher tension with its body than a smaller one. As soon as this voltage drop is equivalent to a body voltage, it causes the reaction corresponding to the body threshold voltage in question. Each of the three reactions corresponds to a different body voltage. Within one species of fish these body voltages are the same and independent of the length of fish.

Since the field strength varies inversely as the square of the distance, adult fish are attracted on account of these correlations by the electrotaxis effect from distances where immature fish are not yet subject to any reaction. This selectivity provides a very necessary and most efficient method of conserving immature fish. By conventional fishing methods, this cannot always be controlled satisfactorily.

The electric power required for a certain electrotaxis range is dependent on the species of fish to be caught and the average length of the fish. In practice spherical electrotaxis ranges with diameters of 6 m (20 ft) to 20 m (65 ft), dependent on species and length of fish, are obtained with powers considerably below 50 kw.

Electrotaxis, fish heading towards the anode in DC or pulsed DC field, is the main effect used to catch fish electrically.

The problem of actually catching fish electrically is how to combine this effect of electrotaxis with suitable mechanical means to get the fish aboard. A series of parameters have to be harmonised with each other in order to avoid disturbances. The problem is explained below using the most difficult example of pumping electrically concentrated fish without nets.

Electro-pump fishing

A shoal of herring is to be pumped from depths between 5 and 40 fathoms by means of an electro-fishing device producing DC pulses, a fish pump and a hose.

Combining the effects of electrotaxis and a fish pump is a very difficult task. Other techniques, for example catching tuna by means of an electrified stick-held dip-net, would not raise so many problems.

For a fishing test a 100 kw 3-phase diesel generator and a main switchboard were installed in the engine room (Fig. 1) whilst the fish pump was fixed on deck (Fig. 2a). The pump hose was lead over the rail in a steel chute (Fig. 2b). The pump hose was sufficient for pumping from a depth of 150 ft with an allowance of 50 ft for pump discharge to reach the hold or other carriers.

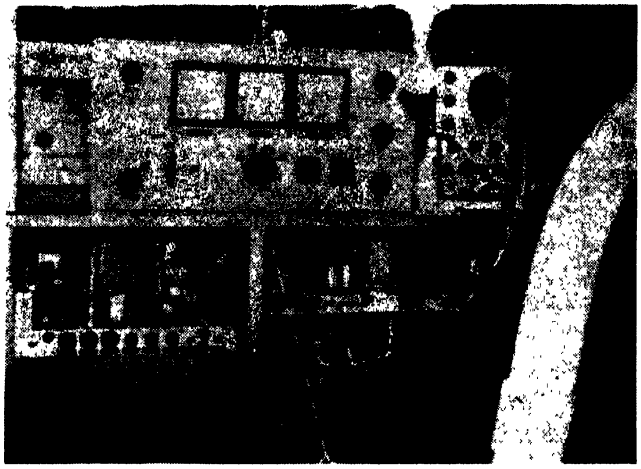


Fig. 1. Pulse generator with instrument and control panel on top installed in engine room. Some covers removed.
Note: On the right below—ignitrons in gimbles measuring cords and oscillope (right).

The hose was in 18 ft lengths, easily coupled together by means of three hinged bolts. The anode (positive electrode) was attached to the end of the pump hose (Fig. 3). The cathode (negative electrode) can be seen in the centre of Fig. 2b (triangular pipe construction).

Fig. 2a. Fish pump on deck—hose to fish hold going from centre of the photograph to the right.

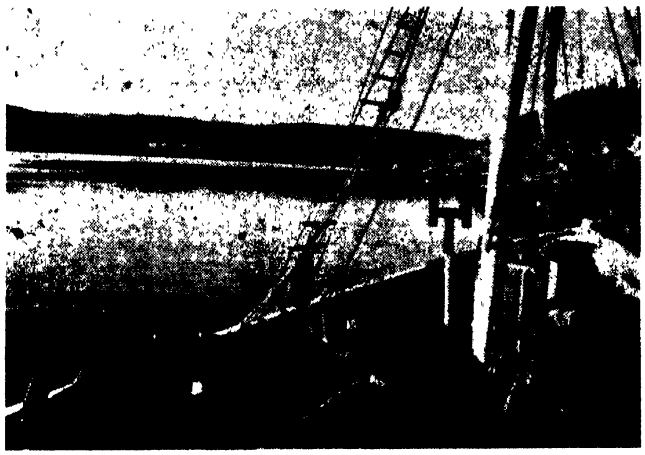


Fig. 2b. Fish pump (right) and pump hose ready to be lowered for netless pumping of fish from the open sea.

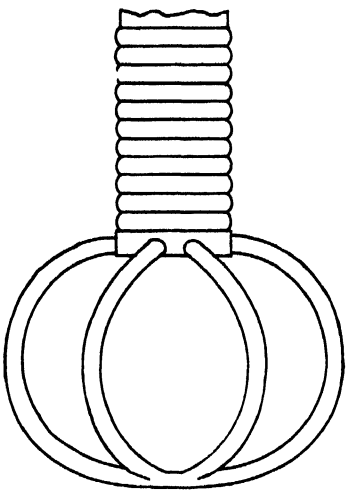


FIG 3 ANODE (POSITIVE ELECTRODE) ATTACHED TO PUMP HOSE END

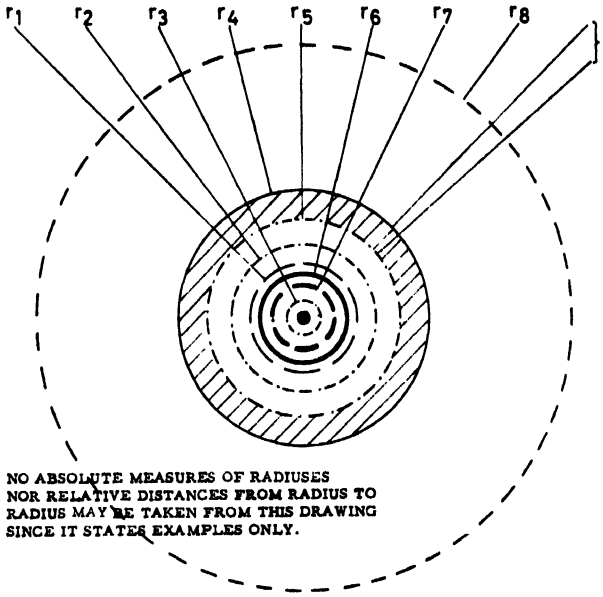
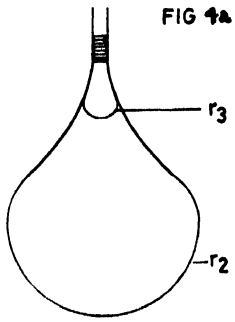


FIG. 4

FIG 4a



THE ACTUAL RELATION BETWEEN r 3 AND r 2 IS APPROX. 1 : 3

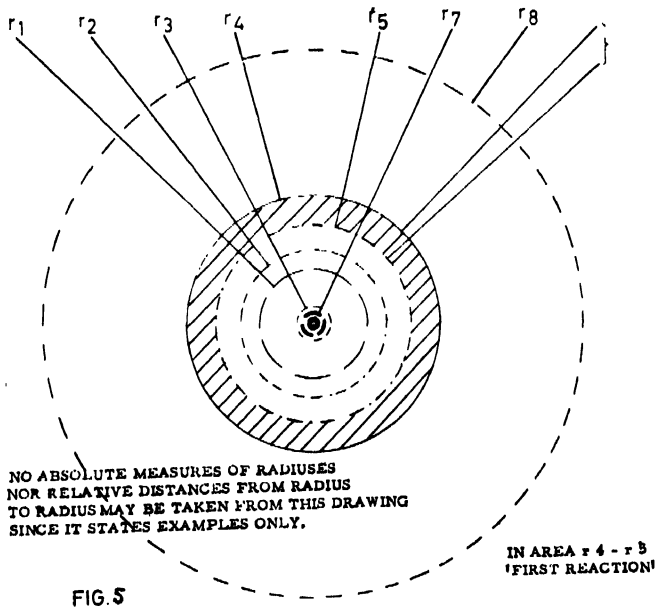


FIG. 5

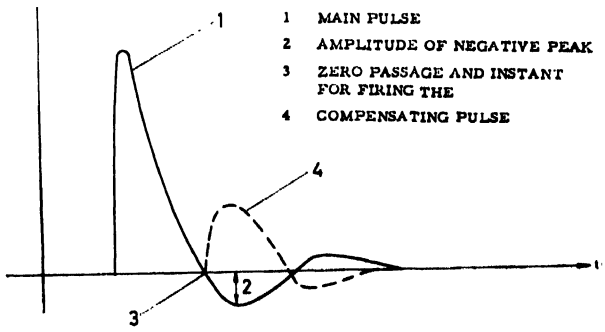


FIG. 6

For operation it is submerged close to the pump hose. The pump hose is lowered or lifted according to the depth of the fish shoals by means of a derrick.

Occurrences around the anode

A number of ranges around the anode influence the fish as shown in:

Fig. 4—r.1 The pump hose end with the anode has a visual chasing range.

r.2 The pump hose opening has a mechanical suction chasing range.

r.3 Within the suction range fish are sucked up; the radius of the suction range is approximately one-third of the radius of the suction-chasing range.

r.4 and 5 The electric field around the anode has in its "outer space" (outside the electrotaxis range) a chasing area (hatched in Figs. 4 and 5) of the first reaction (see Introduction), limited by range 4.

r.5 Then there is the electrotaxis range: within this range all fish head towards the anode and swim straight towards this electrode.

r.6 Inside the range of electrotaxis exists the range, as it might be called, of "indifferent reaction". The reason is that the pulse cables plus sea water have a certain inductance. This inductance affects the pulse, which originally has DC character, causing it to pass through zero and then deadbeat (Fig. 7). If the negative amplitude after the first zero passage reaches or surpasses the threshold voltage for electrotaxis (body voltage) the anode at this instant becomes a cathode to the fish. At the following pulse the electrode is again positive, then passing through zero becomes negative again, and so on. Thus the fish reacts indifferently, i.e. it stops heading and swimming towards the anode.

At a given pulse voltage, the radius of this range of

"indifferent reaction" is influenced by the size of the surface of the anode. Therefore, to reach a large range of electrotaxis, the anode should have a maximum size. On the other hand, the voltage gradient in the water depends on the effective surface of the electrode; the bigger the electrode, the less sharp is the voltage gradient and vice versa. Therefore it happens that pulses with zero passages having negative peak amplitudes large enough to cause this "indifferent reaction" are outside the suction range (see r.3).

r.7 Another and most important radius is the range of electronarcosis.

r.8 The phototaxis range also has influential effects under certain conditions.

All the ranges but the suction range and the suction-chasing range can be assumed to be almost spherical in shape. The shape of the suction range and the suction-chasing range is assumed to have the form of a pear (Fig. 4a) in cross-section and circular in plan.

The problem is to harmonise all these ranges in the following manner:

Fig. 5—r.5 and 2 The electrotaxis range must be larger than the suction-chasing range. The electrotaxis range should enclose as many fish as can be sucked up by the pump after concentration around the hose mouth, but this is limited by the period during which the fish can be kept in the stage of electrotaxis before they sink down or rise up fatigued or stunned by muscular stress. In principle, this depends on the electric power output, the capacity of the pump and the density of the shoal. The capacity of the pump is given within small tolerances. The density of the shoal is taken from the echo recording and according to this the pulse voltage is regulated.

r.9 The electronarcosis range is to be kept smaller than the suction range. If the narcosis range is larger than the suction range, some fish are not able to enter the suction range but get narcotised before they enter the suction range and accordingly they sink down or rise up, thus being lost. If at a given electric power output a great electrotaxis range is to be obtained, which means using an anode with a large surface, the range of electronarcosis is also relatively large and usually larger than the suction range as already mentioned above. Theoretically this could be prevented by decreasing the surface of the anode but, by doing so, the electrotaxis range is also decreased. Also, as already mentioned above, the voltage gradient of a smaller anode is much sharper and the voltage drop in the vicinity of the anode is bigger.

Fig. 4—r.6 Further, the range of "indifferent reaction" must be prevented.

Independently from the question of ranges, there has to be a good timing of the pulse duty cycle.

This problem can be reduced to two main items : to prevent indifferent reaction and electronarcosis. The solution is the so-called Pulse Compensation Method (patented).

According to the principle of the Pulse Compensation Method (Fig. 6), a small compensating pulse is fired at the very instant of zero passage of the main pulse. The width and amplitude of this compensating pulse are similar to that of the negative wave of the main pulse (see also Figs. 7 and 8). Physiologically the fish are no longer prevented from swimming farther towards the anode. But there still remains the range of electronarcosis.

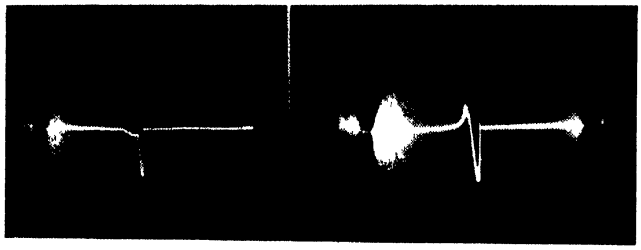


Fig. 7. (left) Oscillogram of pulse with zero passage and considerable negative peak.

Fig. 8. (right) Oscillogram of pulse with overcompensated negative peak by means of positive auxiliary pulse.

When the fish are just entering the electronarcosis range the main pulse is automatically switched off, the compensating pulse still being "on". Because the amplitude of the compensating pulse is much smaller than that of the main pulse, it cannot create narcosis. But it is still big enough to cause electrotaxis, since the fish are now already in the vicinity of the electrode (in other words, the voltage drop close to the anode is small enough).

Various experimental proceedings to optimise some of the parameters are demonstrated in the following paragraphs. Reference is also made to the echograms.

The visual chasing range of the pump hose end is shown in Fig. 9.

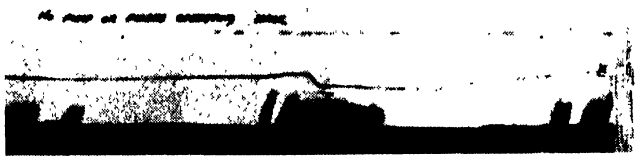


Fig. 9. No pump or pulse operating. The track of the hose shows clearly and the drop in the middle shows where it was lowered.

The suction-chasing range is shown in Fig. 10. It can clearly be seen how suction-chasing starts when the pump is switched on, how it stops when switched-off, and that fish follow the pump hose end when being lowered or raised.

Fig. 10. Echo-sounding diagram with pump on and off. The clear patch was where the propeller disturbed the echo sounding. This figure illustrates suction chasing.

In Fig. 11 phototaxis and some suction chasing can be seen. Phototaxis is a good means to pre-concentrate fish if shoals are not dense enough or, due to the insufficient length of the hose, it is necessary to draw a deep-lying shoal towards the surface and within the vicinity of the hose mouth. In certain cases it can be used as a "light magnet" to pull fish upwards. Phototaxis is also the way to re-concentrate fish after the electrotaxis area has been swept empty before another series of pulses is "shot" according to the pulse duty cycle.

Fig. 11. Light 65 ft down, see track of the lamp: concentrations above and below. Illustrates Phototaxis.

Electrotaxis and re-concentration by light (phototaxis) are shown in Fig. 12. These echograms represent the tremendous effect of electrotaxis and immediate re-concentration when light is switched on again after pump and pulse have been stopped. As long as pulses are "on" herring are pumped aboard.

Fig. 12. Ad. C. E. electrotaxis and re-concentration by light (phototaxis).

The echogram in Fig. 13 shows perfect electrotaxis and herring being pumped (8 tons).

Electrotaxis and electronarcosis

During this trial, the suction-chasing range was made smaller by reducing the pump efficiency by two 10 per cent steps. Electrotaxis was now stronger than the chasing effect of pump suction. Herring were pumped aboard (Fig. 14).

Electronarcosis range was decreased (Fig. 15). These echograms demonstrate another way to overcome the narcosis range. This time the possibility of switching off the main pulse just before the bulk of fish enters the narcosis range was ignored and a lower pulse voltage and a smaller anode was used.

Fig. 15. Pumping herring with lower pulse power and smaller anode—still some narcosis.

The echogram in Fig. 16 records the state where optimum combination of parameters has been achieved (see also Fig. 5).

(a) Electrotaxis range larger than suction-chasing range.
(b) Phototaxis compensating visual chasing.
(c) Electronarcosis range smaller than suction range.
(d) Range of "indifferent reaction" eliminated.
(e) Correct timing for switching off main pulse and only running compensating pulse for itself before fish get narcotised by fatigue.
(f) Right duty cycle for pulses: main pulse and/or compensating pulse switched on and off with re-concentration during the intermissions, e.g. by phototaxis. The operation of the duty cycle: main pulse plus compensating pulse "on", main pulse "off", compensating pulse "off", intermission for re-concentration or drifting into "new" part of shoal, main pulse plus compensating pulse

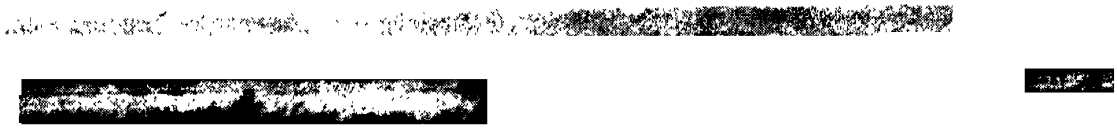


Fig. 13. Ad. C. F. electrotaxis and electronarcosis. On the left electrotaxis enables 8 tons of herring to be pumped, when associated with some electro-narcosis. The hose track is visible on the right.

Fig. 14. Electrotaxis Range larger than suction chasing range.

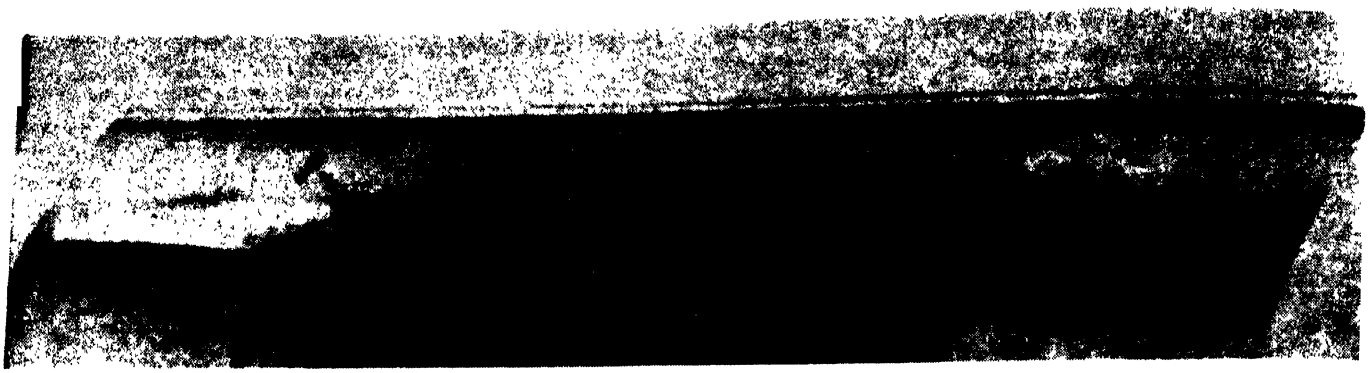


Fig. 16. Ad. D.C. optimum ranges and perfect pumping with almost no narcosis.

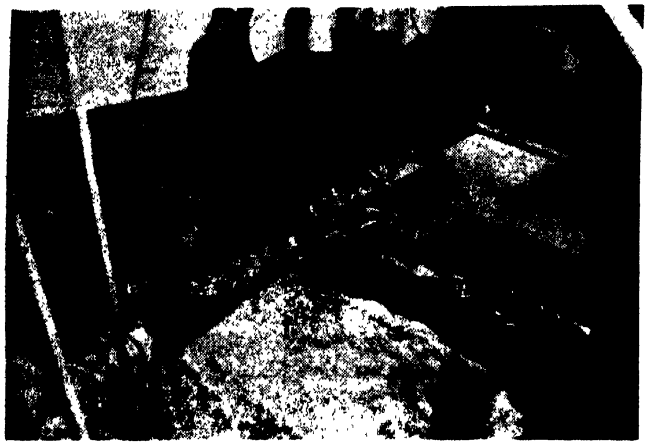


Fig. 17. Pumped fish—having passed the fish pump—are led to the hold. The Water of the fish/water mixture (approx. 40% fish; 60% water) is separated by a provisional fish/water screen.

Fig. 18. Pumped herring leaving the fish/water screen into fish hold.

Fig. 19. First herring electrically concentrated and pumped from sea without nets (rate of damaged fish less than 3%).

"on", and so forth, takes altogether less than three seconds per cycle. This results in a continuous flow of fish aboard.

Note: the echograms shown do not represent a consecutive series of recordings of the step-by-step trials. They are just taken from hundreds of examples of this measuring and trial-and-error development work (see Figs. 17, 18 and 19).

It is actually possible to optimise the various parameters so that they do not work against each other but co-operate in the right manner. Further, it is likely that after this most difficult task (pumping of electrically concentrated fish) has been solved, other electro-fishing problems can be solved more easily if mechanical means other than a fish pump are applied to take the fish aboard. However, it must be stressed that for every species of fish, and also with regard to the intended electro-mechanical gear combination, a series of tests has to be carried out in order to establish the optimum electrical and mechanical parameters.

Notes on the Importance of Biological Factors in Fishing Operations

Abstract

The paper outlines the importance of the distributional and behavioural properties of the exploited fish stock when designing fishing gears and deciding upon fishing tactics. The horizontal and vertical distribution, density of concentration, response to stimuli, general school behaviour, etc., are important factors which must be carefully considered in the construction and operation of fishing gears. The behaviour of fish is furthermore closely associated with light intensity, water temperature, salinity and currents. The authors next indicate the general range of vertical distribution of different exploited species, and discuss the behavioural responses to fishing gear of certain species emerging from recent experiments.

Notes sur l'importance des facteurs biologiques dans la pêche

Résumé

Ces notes traitent de l'importance des caractéristiques de comportement et de distribution du poisson dans le dessin des engins de pêche et des tactiques à employer. La distribution horizontale et verticale, la densité de concentration, la réponse aux stimuli, le comportement général des bancs de poissons, etc, sont des facteurs très importants et doivent être considérés dans la construction et l'opération des engins de pêche. Le comportement des poissons dépend de l'intensité de lumière, de la température de l'eau, de la salinité ainsi que des courants. Ces notes nous donnent ensuite des indications sur la portée de la distribution verticale des différentes espèces et traitent des réactions du poisson et du comportement de certaines espèces envers les engins de pêche, indications basées sur de récentes expériences.

Notas sobre la importancia de factores biologicos en las actividades de pesca

Extracto

Subraya la ponencia la importancia de conocer la distribución y comportamiento de poblaciones explotadas cuando se diseñan materiales y se deciden los métodos de pesca. La distribución horizontal y vertical, densidad de las concentraciones, reacción a los estímulos y comportamiento general de agrupación son factores de importancia que se tienen que tener muy presentes en la construcción y uso del material de pesca. El comportamiento de los peces está estrechamente relacionado con la intensidad de la luz y la corriente, temperatura y salinidad del agua. Los autores pasan a indicar el grado de distribución vertical de diversas especies explotadas y examinan las respuestas a estímulos producidos en ciertas especies por los artes de pesca, examinadas en experimentos recientes.

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IT is important for fishermen to know how fish behave and in this paper the subject is dealt with under three main headings as follows :

(a) Horizontal distribution
(b) Vertical distribution
(c) Response of fish to gear.

Horizontal distribution

Horizontal distribution of an exploited fish stock is usually uneven. The fish tend to form "concentrations" (or aggregations) of varying size, density and permanence. The extent of these differs between species and they often change suddenly and unpredictably. Clearly such behaviour is of great importance to the fisherman in his choice of fish locality, tactics and gear.

Although the distribution of fish and their degree of concentration is always changing, the types of concentration formed by different species fall, in general, into two main categories:

(a) "organised" (Polarised) shoals or schools, the members of which are kept together by mutually attracting forces. This is generally characteristic of the pelagic species (e.g. sardines, herrings, mackerels, tunas and anchovies). Shoals (schools) may vary widely in size, density and permanence but in the shoal the members general y react as a unit. The density of fish in a shoal is usually high.

(b) "loose" (unpolarised) concentrations of individuals (or groups of individuals) brought together and maintained in a reasonably well defined locality by a common external or physiological stimulus, for example, accumulation on a rich feeding ground or in a spawning area. In general, density is less than in shoals, and they tend to cover a wider area.

The distinction between these types of aggregations is not sharp. However, the broad, general distinction between them is important in that the choice of fishing method for exploiting a particular species in an area is often critically governed by these properties. Thus, encircling gears (e.g. ring nets, purse seines, etc.) are particularly appropriate for catching species which form tight shoals, whereas towed or drifting gears (e.g. trawls, driftnets, bottom and pelagic lines, etc.) are more suitable for species forming looser, more diffuse concentrations. It is often possible from a general knowledge of how the species aggregate to make a first choice of fishing gear in a new, unfished area.

Although the horizontal distribution and degree of concentration of most species vary widely (both long and short term) they tend to follow a regular, seasonal pattern especially during spawning and/or feeding seasons. Knowledge of these seasons is, therefore, of major importance. Examples of their importance are found in the herring and cod fisheries off the west coast of Norway. Both of these fisheries are centred on dense seasonal aggregations of fish during spawning. Other fisheries are also based on these stocks in other seasons, but in quite different localities.

Other regular features of horizontal distribution and aggregation relate to the distribution of different sizes and age-groups. In many species the young, unmarketable members of the stock occupy, or concentrate in, different localities than the older, marketable ones. For example "nursery areas" of plaice are usually situated in shallow water close to the coast, but the fish gradually move into deeper water with age; similarly, the young stages of most clupeoid species are mostly located in reasonably well defined areas. Therefore, information on the whereabouts of the "nursery areas" and seasonal main aggregation centres of older, marketable fish can be important to fishermen.

Superimposed on these "regular" patterns of behaviour are local, short-term variations in distribution and aggregation within any area, resulting from variations in physical, chemical or biological factors. In the main these variations are "irregular" and they cannot usually, as yet, be predicted in advance. They contribute largely to the uncertainty and fluctuating fortunes of fishing from day to day.

Such variations may be caused by many different factors which may differ from place to place, time to time and between species, thus making their identification difficult. Much useful information on these variations can be obtained by detailed studies on:

(a) food and feeding habits (including the presence of principal food items).
(b) predator species.
(c) depth of water; type and topography of sea bed.
(d) temperature, salinity and current systems.
(e) local weather conditions.

The investigations of cod in the Barents Sea[6,3] and of herring in the Norwegian Sea[2] have shown close associations between the distribution of local aggregations of these species and particular temperature conditions. Such results show clearly the potential value of temperature records as indicators of likely centres of aggregation of cod and herring respectively.

Many examples of the use of environmental information in fish location are to be found in the fisheries literature, covering a large number of species in different parts of the world, and they clearly illustrate its potential value[1,5,4]. In the course of fishing, too, fishermen acquire an extensive working knowledge of the local "haunts" of the main commercial species and of the signs of their presence. While such information is gathered by fishermen and is used in their choice of fishing grounds, more detailed information demands painstaking long-term scientific studies of the physical, chemical and biological properties of the environment in relation to the distribution of fish. Such investigations are being carried out by fishery scientists all over the world, with a view to predicting both general and more detailed aggregations of exploited fish stocks.

Vertical distribution

As well as having uneven horizontal distribution, fish are usually also unevenly distributed in depth. Clearly, this is also of major importance in day to day fishing. It is also important to the gear technologist in assessing possible improvements in gear design, rigging and operation for different species. For example, the question of the importance of headline height in bottom trawls is critically governed by this factor.

Echo sounders have greatly increased knowledge of vertical distribution and its variations. In pelagic trawling for herring the depth at which the net is towed is determined from echo-sounder observations—indeed they are now considered to be indispensable for this method. Although for most demersal species precise information about vertical distribution is still limited, because of the greater difficulty of detecting fish by echo sounder on or near the sea bed, the introduction of narrow beam, high frequency sounders and improved display techniques have greatly improved the effectiveness of echo sounding and led to better understanding of the depth ranges of the main commercial species and the ways in which these vary. Clearly variations in vertical distribution may greatly affect the efficiency of particular fishing gears. This is especially so for bottom and pelagic trawls and driftnets whose catching surface covers a very small part of the total water column. Of particular importance are the diurnal changes in vertical distributions. For some species these are of sufficient magnitude to seriously reduce the effectiveness of bottom fishing gears (e.g. trawls) in darkness and of pelagic gears (e.g. driftnet), in daylight.

The general features of vertical distribution of fish are closely associated with their feeding habits. Thus species (e.g. most flatfish) which feed mostly on bottom-living organisms during their adult life are adapted to a demersal life and spend most time on or close to the sea bed. Similarly, most of the clupeoids, which are dominantly plankton feeders spend a large part of their life away from the sea bed. Others (e.g. cod) have a more varied diet, and so have a more variable vertical distribution. In addition to this general association with feeding habits, the vertical distribution, especially of pelagic species, is also associated with other environmental factors, such as light, temperature and salinity.

Light—The activity and behaviour of many species of fish vary markedly with the light intensity and the diurnal variations in vertical distribution of species such as herring, sardine and pilchard are closely associated with the diurnal light cycle. Most fish seem to have an optimum light intensity, which they will normally seek in accordance with light penetration affected by climatic factors (cloud cover, etc.) and the turbidity of the water. It is well known that, in some areas, the level to which herring rise at night is often deeper on bright moonlit nights than on dark ones, thus markedly affecting the efficiency of driftnet fishing.

Temperature and Salinity—The vertical temperature structure may also influence vertical distribution, either directly or indirectly, through its effect on the distribution of food organisms. In the northern North Sea in summer, the upward migration of herring at night often appears to be restricted by the strength of the temperature

discontinuity layer, the thermocline. This may influence their accessibility to driftnets or ring nets. In regions of mixing of water masses of different physical characteristics (e.g. oceanic and polar water) marked temperature and/or salinity stratification is also often present, and this again influences the vertical distribution of fish, which may only be found within narrow depth limits, characterised by particular temperatures and/or salinities. Other factors which may also affect vertical distribution include the oxygen content of the water, the distribution of predators and climatic factors (weather, moon).

Behavioural responses to fishing gear

How fish behave to fishing gear also affects their catchability and such knowledge is of great importance to gear technologists in designing and operating different types of gear. The recent application of underwater photographic and television techniques, the use of echo sounders, frogmen, underwater observation chambers including a submarine with direct observation windows, experimental work in tanks and the results of comparative fishing experiments have provided some important pointers to the principal factors involved. The results of some of these studies can be summarised as follows:

(a) In conditions where vision is possible, fish in the vicinity of towed gears (e.g. trawls, Danish seines) on the sea bed respond by being herded inwards by the sweeps and bridles and forward by the net, at about the same vertical level. There is no clear evidence of fish avoiding the gear by moving upwards, out of its sphere of operation. However, in midwater avoidance of pelagic trawls does sometimes appear to take place by fish moving downwards. The distance from the gear at which these responses take place differs between species (it seems from tank observations that it is greatest in the active shoaling species) and varies according to the visibility of the gear. The effectiveness of the fishing gear in defeating this behavioural response is therefore a function of its visibility and the speed with which it is towed.

(b) In darkness (light intensities less than about 0·5-0·05 lux), these responses do not appear to take place, and the orientation and movement away from the gear are much less pronounced. Observations in tanks imply that the generation of noise (both high and low frequencies) and of pressure gradients by the towed gears does not appear to produce marked directional behaviour responses in darkness (Chapman, this Congress). Further, the level of activity of fish is generally lower and their "organisation" is less in darkness than in daylight, thus reducing their ability to escape from towed gears.

(c) The entry of fish into traps or other stationary or drifting gears (driftnets, trammel nets, etc.) often appears to be critically governed by their visibility, which is a function of their conspicuousness, the incident light intensity and the clarity of the water. Similarly, the taking of bait on lines is sometimes partly governed by its visibility. These results point to vision as one of the most important factors governing the responses of fish to fishing gear. Although it is well known that fish are sensitive to sound stimuli over a wide range of frequencies (they emit sounds themselves), the evidence available at present suggests that sounds play a relatively small role in governing the reactions of fish to gear or to the fishing unit as a whole. Thus, the very high frequencies produced by echo sounders do not seem to produce marked flight or other responses in herring shoals or the concentrations of other species; similarly, there is no substantial body of evidence to support the view that the engine and propeller noises of ships cause major flight reactions except when the fish are close to the ship, although it is often claimed that the combined noises of large numbers of fishing vessels cause fish in an area to "take off".

A possible feature of fish behaviour about which little is yet known is the ability of fish to learn to avoid fishing gear when they are continually exposed to it. Laboratory experiments have shown that fish can be taught to behave conditionally (e.g. to attempt to take food in response to a stimulus other than food) itself so that some element of "conditioning" or learning might occur among exploited fish concentrations. More information is undoubtedly needed on this.

Conclusions

Success of fishing operations is clearly governed by many complex factors concerned with the distribution and behaviour of the exploited fish stocks, and these may change rapidly and sometimes unpredictably. Although this uncertainty is perhaps most marked in vertical distribution the main elements are now clear enough to be useful. Pelagic feeding species such as the herring may be distributed at almost all levels, according to environmental conditions (especially the distribution of food and light), while others such as hake and cod, although mainly bottom living species may frequently be found well above the sea bed. However, with the exception of oceanic pelagic species, such as tuna, almost all species are found frequently on the sea bed. Of these, only the typical flatfish are normally found only within a few feet of it; most others may at times be found near to and even extending well above the bottom, and it is these species for which the facility to adjust trawls either to give more height or more spread would be invaluable. In general, the most modern types of echometer will show when either is desirable—as they will show when a species is (and the trawl should, therefore, be) in midwater.

The principal stimulus governing the behaviour of fish to many gears is light, and on incident light intensity, the clarity of the water and the visible properties of the gear (e.g. colour and thickness of twine; size of mesh, etc.), depend the type and magnitude of the fish's responses. (Blaxter, Parrish and Dickson, this Congress).

This conforms with the marked responses made by many species of fish to artificial light stimuli and in many fisheries lights are used for aggregating or guiding fish before capture.

continued on page 560

Tuna Behaviour Research Programme at Honolulu

Abstract

The behaviour research programme of the Biological Laboratory of the U.S. Bureau of Commercial Fisheries at Honolulu is conducting studies of the sensory abilities and the behaviour of tuna. The methodologies of the comparative psychologist and ethologist are being utilised to gain a basic understanding of the ways in which a tuna responds to its environment. At present, detection of underwater sound, feeding behaviour, social behaviour, vision, and the changes in behaviour throughout the day are being investigated. These studies are conducted at sea using underwater viewing ports in the research vessel *Charles H. Gilbert* and in a floating raft, *Nenue I*, and in eight shoreside tanks at Kewalo Basin, Honolulu.

Le programme de recherche, à Honolulu, sur le comportement du thon.

Résumé

Dans le cadre du programme de recherche sur le comportement du poisson, le Laboratoire biologique de l'U.S. Bureau of Commercial Fisheries à Honolulu, conduit actuellement des études sur les facultés sensorielles et le comportement des thons. Les méthodologies de psychologie et d'éthologie comparatives ont été utilisées pour arriver à une base de compréhension de la façon dont réagit le thon à son environnement. Jusqu'à ce jour, la vision, la détection des sons sous-marins, l'habitude alimentaire, le comportement social et les changements de comportement durant la journée ont été observés. Ces études ont été conduites en mer, à travers des hublots sous-marins montés dans la coque du bateau de recherche *Charles H. Gilbert*, sur un radeau flottant, le *Nenue I*, et dans hit bassins à Kewalo Basin, Honolulu.

Programa de investigaciones del comportamiento del atún en Honolulu

Extracto

Como parte del programa de investigaciones del comportamiento del atún, el Laboratorio de Biología de la Oficina de Pesca Industrial de los E.U.A. en Honolulu, estudia la capacidad sensorial con relación al comportamiento. Se emplea la metodología de la sicología y etiología comparativas para tener un conocimiento básico de la manera en que el atún reacciona ante su ambiente. Actualmente se investigan la vista, la determinación de los sonidos subacuáticos, el comportamiento durante la alimentación y en sus relaciones con otros miembros del cardumen y los cambios del comportamiento durante el día. Estos estudios se realizan en la mar empleando los portillos submarinos del buque investigador *Charles H. Gilbert*, en una balsa flotante *Nenue I* y en ocho estanques en la costa en Kewalo Basin, Honolulú.

by

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TUNA behaviour studies are one of eight major research endeavours of the Biological Laboratory of the U.S. Bureau of Commercial Fisheries at Honolulu. The objective of the behaviour research is to gain a basic understanding of the behaviour and the sensory abilities of tuna. An understanding of tuna behaviour is expected to be useful in the future design of fishing gear and fishing methods and in locating tuna.

The research programme was originally conceived in 1957 as a study of stimuli which attracted or repelled tuna to or from pole-and-line tuna fishing boats. Between 1958 and the present the orientation of the research has slowly changed toward a more general query with the potential of more generalised application.

Both a sea phase and a shore phase were begun in 1958. The first problem of each was to develop methods of studying the fast swimming pelagic tunas. Progress in these efforts was reported for the sea phase by Strasburg and Yuen (1960)[4] and for the shore phase by Nakamura (1962)[3]. By 1960 the oceanographic research vessel *Charles H. Gilbert* had been equipped with stern and bow underwater viewing ports, and feeding behaviour of tuna had been observed and photographed at sea. By 1961 the skipjack, *Euthynnus pelamis*, had successfully been kept and studied in shoreside tanks at Kewalo Basin, Honolulu, for almost six months. In 1962 a 12 ft by 12 ft raft with a viewing chamber beneath it was

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While a large body of information has been accumulated there are still many unknowns concerning the detailed behaviour responses of fish, both to natural environmental, and to artificial influences. This is largely due to the difficulties of observing fish in the sea directly. The recent development of high resolution echo sounders and techniques of underwater observation, and the growth of experimental aquarium work have, however, provided basic information. Work involving personal observation of fish in the sea, under varying environmental conditions and throughout the diurnal light cycle, is needed in order to confirm the pointers obtained from aquarium studies and by applying less direct methods. The need for appropriate underwater vehicles or chambers, for conveying observers to depths up to 80-100 fathoms. cannot be too strongly stressed. The use in the U.S.S.R. of a submarine with observation windows for this purpose is especially interesting.[7]

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designed and built by R. Gooding and was successfully used as a passive observation platform to observe and photograph dolphin fish, *Coryphaena hippurus*, and other large predators at sea. By the end of 1962, a total of eight tanks had been designed and erected for specific investigations at Kewalo Basin. In 1963 these facilities are being used by six biologists and aides engaged in analysing the enigmas of tuna's behaviour.

Two types of study are being conducted, those of sensory ability and those of behaviour. The methodologies of the comparative psychologist and the ethologist are being applied to species whose ways have long been observed by fishermen. Application of these methods is increasing the rate at which understanding of tuna behaviour increases.

Both visual and hearing abilities are being quantified with captive tuna at Kewalo Basin. The tuna are taught to associate an underwater sound or image with food or, in some cases, an electric shock. After training is completed, the tuna reacts to the visual or sound stimulus in the absence of the food or electric shock. The conditioned response indicates that the sound or image was perceived by the tuna's sensory system. A careful choice of stimuli make it possible to describe the ability of the sensory system to perceive the environment in standardised and generalised terms.

More specifically, the visual acuity of little tuna, *Euthynnus yaito*, and skipjack is presently being measured. Such data provide information on the ability of these tuna to see an object of a certain size at various light intensities and distances underwater. In the sound studies the range of frequencies tuna can perceive and the minimum intensity that can be perceived at each frequency are being described.

Behaviour research both at sea and in shoreside tanks is concentrated upon feeding behaviour, social behaviour, and changes in behaviour throughout the day and night. Most sea work is directed at skipjack and yellowfin, *Thunnus albacares*, whereas most shore work is on skipjack, little tuna and bonito, *Sarda chiliensis*. The work on bonito is in co-operation with J. Prescott at Marineland of the Pacific in California.

At sea the stern underwater ports on the *Charles H. Gilbert* have provided an opportunity to observe feeding behaviour of tuna. Experiments were conducted in the waters of Hawaii and the Line Islands to determine the influence of different species of bait and artificial feeding stimuli on the feeding behaviour of skipjack (Yuen 1962)[7]. The fishing techniques of the Hawaiian sampan fleet were used: skipjack found by looking for bird flocks, were attracted to the vessel by chumming live bait into the sea, and were then caught on pole-and-line. Measurements were made of changes in catch rate and in the feeding rate (number of feeding attacks per fish per minute), which resulted from changing from live to dead bait, from one species of bait to another, or from turning off and on a water spray over the surface of the water. Catch rate increased when water sprays were turned on and decreased when they were turned off, when any one of six different species of chum was used. Both catch rate and feeding rate increased when living bait was chummed and decreased when dead bait was chummed. Catch rate is higher with the live bait, because movement is one of the stimuli inducing feeding behaviour of skipjack, and because dead bait tends to drift away behind the vessel and take the skipjack away with it. Experiments using different species of bait are still in progress.

While being fished by the pole-and-line techniques, surface schools of skipjack characteristically dive or sound, returning to the surface seconds or as long as 28 min later (Strasburg 1961)[5]. Zero to eight dives were observed per school in Hawaiian waters and the frequency of diving was found to be associated with the occurrence of a lizard-fish, *Synodus variegatus*, and a squirrelfish, *Holocentrus lacteoguttatus*, in the stomach contents of the skipjack. It was hypothesised that these two species were more attractive than the live bait used by the fishermen and that the skipjack dived in pursuit of them.

Tuna schools are usually composed of fish of the same species and approximate size. Occasionally, pole-and-line or purse seine tuna boats catch both skipjack and yellowfin in a single fishing operation. Observations from the stern chamber of the *Charles H. Gilbert* have made it possible to study the structure of the school or schools from which such mixed catches are made (Yuen in 1963)[8]. When underwater movie sequences of such schools were analysed, it was obvious that each species tended to school with its own kind even though fish of the other species were near. A higher frequency of groups of a single species was observed than would have been expected if the fish schooled indiscriminately with the other species.

The floating observation raft is being used to discover the ecological significance of floating logs or flotsam to pelagic fishes. The reason that large numbers of dolphin fish and occasionally yellowfin and skipjack are found in the immediate vicinity of floating objects has been a debated question among fishermen for years. This study should provide some insight into the problem.

The three underwater viewing ports in the bow of the *Charles H. Gilbert* have been used to observe tuna, porpoise, flying fishes, and large plankton organisms. Most small fish dart rapidly away from the moving ship, but tuna and porpoise swim within view of the bow windows for prolonged periods of time. The bow viewing ports made it possible to observe in detail the behaviour of porpoise when riding the bow wave (Yuen 1961).

Very loose schools of skipjack have been observed in the central Pacific, with 7 to 18 yards between fish. These schools, 3 to 6 ft beneath the surface, were only one fish deep. During periods of observation when small numbers of natural prey were sighted by the skipjack, a vertical barred colour pattern appeared on the skipjack, and two or three of the fish nearest the prey organisms converged on them and fed. We have not yet succeeded in observing tuna in a feeding frenzy on natural prey concentrations, although we have attempted to do so by

heading the ship through areas marked by the surface splashes of feeding fish. Although the tuna were sighted by the underwater observer, they dived immediately and were not visible for prolonged periods.

Observations from the bow chamber on large plankton organisms in daylight and, by their luminescence, at night were interesting but difficult to record in numerical terms. It is hoped that the bow chamber can be used to estimate the abundance of surface fishes, but perhaps its greatest value will continue to be as a tool for making observations on marine mammals and fishes as the ship is actually moving with and within surface schools.

Direct observations at sea can be made on tuna that are either attracted near the observer by food stimuli, floating objects, or some other attractant, or that can be successfully followed at distances within 100 ft. This limits the spectrum of behaviour which can be observed at sea to feeding and schooling. In the shoreside tanks other aspects of behaviour can be examined, and feeding and schooling behaviour can be given closer scrutiny.

On shore the detailed patterns of tuna behaviour are first described. Whenever possible the function of the behaviour is determined. If the function is not obvious, experiments are devised to define the utility of the behaviour to the tuna. The functions of most of the observed patterns of behaviour have not yet been recognised. At present certain mouth movements, believed to be important in olfaction and food searching behaviour, are being investigated. The possibility of an olfactory function to the tuna's mouth movements was suggested by an anatomical study of the olfactory capsule of skipjack by Gooding (in 1963)[1]. An accessory sac of the olfactory capsule is compressed when the mouth is closing and inflated while the mouth is opening. This pumping seems to suck water into the naris and over the olfactory sense organ with each opening of the mouth.

Another interesting behaviour of tuna is the change from the typical striped coloration to a vertically barred coloration in skipjack (Nakamura 1962)[3]. This change results when a food stimulus is presented to a skipjack that has not eaten recently. A skipjack that has just eaten its fill does not take on the vertical pattern. The significance of this colour change is not yet known.

In addition to describing behaviour patterns and attempting to determine their function, the changes in behaviour, especially feeding motivation, occurring throughout the day are also being studied. The time of day when a tuna contacts prey and the amount of prey contacted can be expected to greatly influence the response of tuna to food stimuli during successive hours. For example, if skipjack are fed to excess all day long, they eat over half the food they will take during the day in the first three hours of daylight (Nakamura 1962)[3]. Presently, the variations in response to food are being associated with the previous prey-contact history of a tuna.

The present state of knowledge on tuna behaviour was recently summarised by Magnuson (in 1963)[2]. The inability to observe tuna behaviour directly at sea prior to 1958 greatly restricted the accumulation of knowledge. Now the tuna, still evasive and difficult to work with, is subject to the close scrutiny of the ethologist and comparative psychologist both in the field and in the laboratory. The understanding that these studies are providing should give man an additional advantage over the tuna in future exploitation.

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Shrimp Behaviour as Related to Gear Research and Development

1. Burrowing Behaviour and Responses to Mechanical Stimulus

Abstract

The data presented in this paper on the burrowing behaviour of pink shrimp (*Penaeus duorarum*) are part of a current study on general shrimp behaviour by the U.S. Bureau of Commercial Fisheries, Gear Research Station, Panama City, Florida. Shrimp were released on the bottom or placed in bottomless cages and their activity was observed over 24 hr periods by divers or with closed circuit television. All shrimp studied burrowed during daylight hours and showed varying degrees of nocturnal activity. Activity was observed between 19.00 hours and 04.39 hours with a maximum occurring between 19.00 hours and 23.15 hours. A correlation between burrowing behaviour and moon phase or light level is indicated. Two general methods of burrowing were observed that allowed all animals to penetrate the bottom to just below the surface of the substrate. A water circulation system was noted in burrowed shrimp, and they were observed to draw deeper into the bottom under certain conditions of mechanical stimulation. Some of the data and illustrations given in this paper are being published elsewhere as observations on the burrowing behaviour of pink shrimp, *Penaeus duorarum* Burkenroad, C. M. Fuss, 1963 (in manuscript). Supplementary data and observations by Frederick Wathne outline the reaction of shrimp to electrical gear devised to facilitate catching.

Le comportement des crevettes envers les engins de pêche.

Résumé

Les données présentées dans cette communication sui l'havitude qu'ont les crevettes roses (*Penaeus duorarum*) de se terrer, font partie d'une étude générale sur le comportement des crevettes menée par l'U.S. Bureau of Commercial Fisheries, Gear Research Station, Panama City, Florida. Des crevettes ont été mises en liberté sur le fond ou placées dans des nasses sans fond pour observer leur activité par période de 24 heures en scaphandriers et aussi avec la télévision en circuit fermé. Les crevettes étudiées manifestaient divers degrés d'activité nocturne et se terraient surtout pendant le jour; on a observé que l'activité durait de 18 h à 4.?9 h avec maximum entre 19 et 23.15 h. Les observations indiquent qu'il existe une relation entre l'habitude de se terrer et les phases lunaires ou l'intensité de la lumière. Deux méthodes générales ont été observées qui permettaient aux animaux de pénétrer le fond, au dessous du substrat. Il a été observé que les crevettes enfouies avaient un système de circulation d'eau, et qu'elles se retiraient plus profondément dans le fond sous certaines conditions de stimulation mécanique. Quelques unes des illustrations et informations de cette étude ont été publiées ailleurs, comme "Observations sur le comportement des crevettes roses" (*Penaeus duorarum*) Burkenroad, C. M. Fuss, 1963 (en manuscrit). Des informations supplémentaire des observations par Frederick Wathne résument la reaction des crevettes à l'equipment électrique inventé pour faciliter la prise.

Comportamiento del camarón con relacion a las investigaciones para perfeccionar el material de pesca

Extracto

Los datos que contiene esta ponencia, relativos a los hábitos excavadores del camarón rosado (*Penaeus duorarum*), son parte de un estudio de actualidad sobre el comportamiento general de estos crustáceos que se realiza en la Estación de Investigaciones de Material de Pesca de la Oficina de Pesca Industrial de los E.U.A. en Panama City, Florida. El camarón se soltó en el fondo de cajas o se colocó en cajas sin fondo y su actividad se observó durante períodos de 24 horas por buzos o con televisión de circuito cerrado. Todo el camarón estudiado se enterraba de día y desplegaba actividad más o menos intensa de noche. Se observó actividad entre las 19.00 y las 04.39 horas con un máximo entre las 19.00 y las 23.15 horas. Se indica la existencia de una relación entre la actividad excavadora y la fase de la luna o la intensidad de la luz. Se observaron dos maneras generales de hacer galerías que permitían a los animales penetrar en el fondo o quedarse inmediatamente debajo de la superficie del substrato. Se observó que el camarón enterrado mantenía un sistema de circulación de agua y que bajo ciertos estímulos mecánicos seenterraba hasta el fondo. Algunos de los datos e ilustraciones que se dan en esta ponencia se van a publicar en otro lugar como observaciones de los hábitos excavadores del camarón rosado, *Penaeus duorarum* Burkenroad, C. M. Fuss, 1963 (en manuscrito). Adicional información y observaciones de Frederick Wathne delinea brevemente las reacciónes de los camerones a equipaje eléctrico inventado para facilitar la captura.

by

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THE Gear Research Station, U.S. Bureau of Commercial Fisheries, Panama City, Florida, recently initiated a shrimp behaviour study as part of the gear research project. Hitherto little effort has been devoted to studies of their behaviour. As the effects of certain aspects of behaviour on the efficiency of fishing gear are profound, gear development is directly related to animal behaviour.

Instead of, as in the past, relying on laboratory observations the plan was to study the animals in their natural habitat by using diving equipment, underwater motion pictures and closed circuit television.

Methods

Pink shrimp (*Penaeus duorarum*) were obtained by night trawling with the vessel *George M. Bowers* in St. Andrew Bay, Florida. They were removed to an observation area immediately adjacent to the Panama City, Florida, marina, approximately 1 mile from the capture area.

Shrimp were separated into 10 mm total length size groups and held in live tanks during transfer. While under observation, they were placed in 3 ft square bottomless metal frame cages covered with small mesh trawl webbing. The cages were secured to the sea bottom by pushing their legs into the sediment.

Observations were made at half-hour intervals during 24 hr periods by divers using self-contained underwater breathing apparatus. Underwater flashlights were used at night, with the illumination interval kept at a minimum. Diver observation proved more efficient than closed circuit television observations, as a diver can position his face mask within a few inches of the animal and

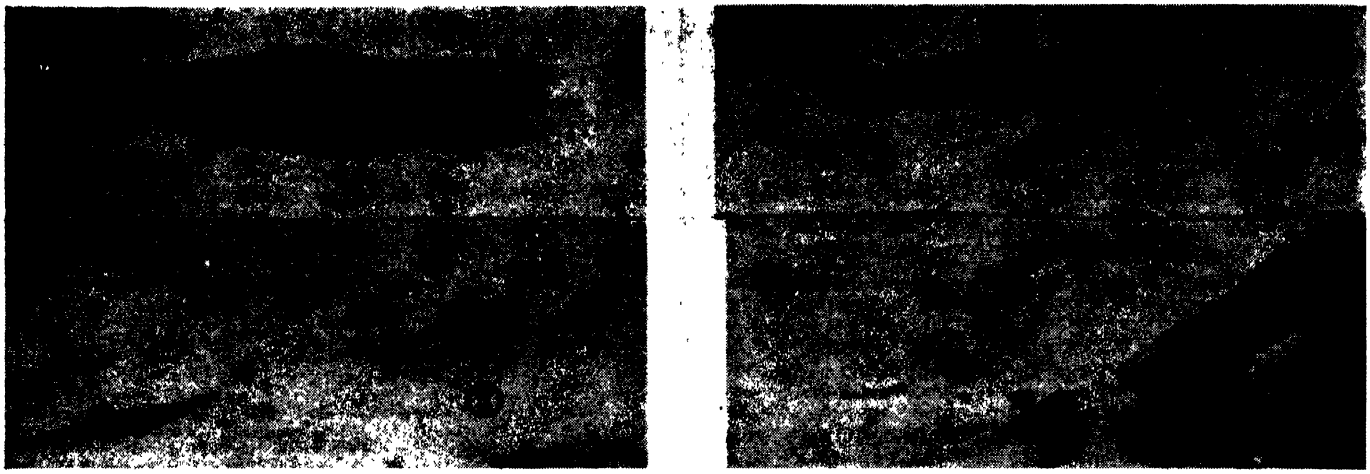

Fig. 1. Stages of burrowing.

view from various angles. Five measured shrimp were placed in the cage at approximately 13.00 hrs on the first day and at the end of the period the cage was removed and the depth of burrowing measured with a millimetre ruler. The shrimp were gently probed until they vacated their burrows and the depths of the depressions were measured. Fresh shrimp were used in each series.

For detailed observations of the mechanics of burrowing, individual shrimp were released on the bottom and their activity was recorded with a 16 mm Bolex H16-R underwater motion picture camera. Vertical views of the animals in the sediment were obtained by using plexiglass containers measuring 12 in square and 1 in wide. The containers were filled with about 6 in of sediment and were either placed on the bottom or held on the surface while individual shrimp were allowed to burrow.

To determine responses to mechanical stimulation, burrowed shrimp were probed with a diving knife or disturbed by lengths of chain that were dragged over them. These responses were also recorded by underwater motion pictures.

Results

Shrimp released on the bottom during daylight usually burrow immediately using one of two general methods. In one approach the animal grasps the substrate with the walking legs, thereby holding itself in position while setting up a water current with the swimming legs. The induced current, flowing beneath the body, scours an initial furrow into which the animal settles. The shrimp then ploughs ahead into the anterior end of the depression, using the walking legs to force itself farther into the sediment. At the end of the ploughing phase of the burrowing process, the shrimp settles vertically into the substrate using its walking legs to force the bottom material laterally and upward around its body. Immediately after the shrimp burrows, there is a slight furrow between two small mounds marking the anterior-posterior plane of the shrimp body. Within a short time all external signs of the burrowed shrimp have usually disappeared and visual detection is very difficult.

The second observed method of burrowing differs from the first by the elimination of the scouring phase, with the animal ploughing immediately into the bottom and then settling. (Fig. 1)[2].

The measurements given in Table I for the depth of burrow indicate a correlation between shrimp size and degree of penetration into the sediment. This correlation apparently depends on body depth of the individual animal since all shrimp were observed to burrow to just below the surface of the substrate. In most cases even the antennae and eyestalks were completely concealed.

To determine the validity of depth of burrowing measurements in the observation area, five 130-140 mm shrimp were placed in a cage in the capture area and their burrow measurements were recorded. Depth of burrow for these individuals ranged from 38 to 45 mm. No significant changes in burrow depth were observed with differences in bottom material, except that a number of various-sized shrimp, released on hard sand bottom just offshore of St. Andrew Bay, experienced difficulty in penetrating the bottom.

Diurnal cycles

The pink shrimp remained burrowed during daylight and showed varying degrees of nocturnal activity. (Tables II and III). To the nearest half hour, the mean time of emergence for all animals studied was 19.00 hrs and the mean time of burrowing was 04.30 hrs. Activity periods ranged in length from 3·5 hrs to 10·5 hrs with a mean of 9·3 hrs.

Fig. 2 shows the degree of activity in each series of observations. Times of maximum activity ranged from 19.00 hrs to 23.15 hrs.

From the data shown a correlation between moon phase or light level and activity can be derived. Activity is generally more restricted during full moon than during new moon.

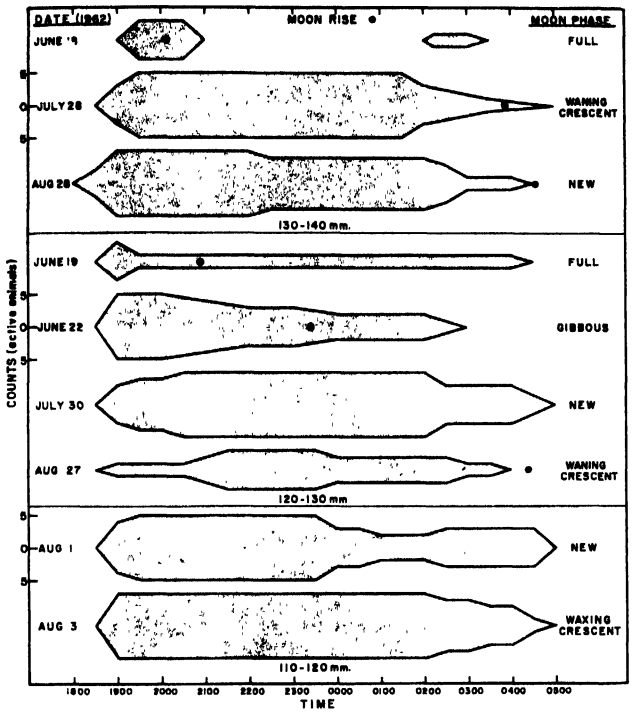

Fig. 2. Activity periods of three size groups of pink shrimp.

Table I—Depth of burrow measurements (millimetres)

Length groups		
110-120 mm	120-130 mm	130-140 mm
38	38	50
31	38	50
30	32	50
30	32	45
30	28	45
29	28	45
28	25	45
28	25	45
28	25	38
27	25	38
27	20	38
25	—	35
25	—	33
25	—	32
25	—	32
20	—	30
20	—	25
Mean 27·4	Mean 28·7	Mean 39·7

Table II—Time first shrimp emerged from burrow (to nearest half hour)

Date (1962)	Length groups 110-120 mm	120-130 mm	130-140 mm
15 June	19.30	——	19.30
16 June	19.30	19.30	19.30
17 June	19.30	——	——
18 June	——	——	19.30
19 June	——	19.00	——
22 June	——	19.00	——
28 July	——	——	19.00
30 July	——	19.00	——
1 August	19.00	——	——
2 August	——	——	19.00
2 August	19.00	——	——
3 August	19.00	——	——
27 August	——	19.00	——
28 August	——	——	18.30

Table III—Time last shrimp burrowed (to nearest half hour)

110-120 mm—Aug. 2, 05.00, Aug. 4, 05.00.
120-130 mm—June 23, 04.30, July 31, 05.00, August 28, 04.00
130-140 mm—June 19, 03.30, July 29, 05.00, August 29, 04.30.

Initial stimulation to the dorsal body surface of burrowed pink shrimp caused the animal to withdraw immediately into the bottom sediment. If the stimulation was continued for a few seconds, or applied to the side of the burrowed shrimp, an escape reaction in the form of a vertical hop would usually take place.

A water circulation mechanism was observed. Two small holes in the substrate were usually visible (one near the tip of the rostrum, the other usually to the side of the rostrum) but occasionally at other positions. Dye injected into the water above the burrowed animal, to determine which opening served as the inhalant syphon, showed that the hole near the tip of the rostrum is generally the inhalant opening, but the flow is reversible, apparently for clearing the channel of debris.

It was observed that shrimp will occasionally use one of the first walking legs to help form the lateral opening of the circulation system. There also seems to be a cavity below burrowed animals which serves some function in the system. Dye injected into the sediment just below the abdominal segments would be ejected from one of the system openings.

Discussion

The *in situ* approach to the study of shrimp behaviour was chosen to eliminate, as far as possible, the undesirable effects of habitat modification. A compromise was necessary, however, to facilitate continuous observations. Tidal currents, and resulting poor visibility in the capture area, prevented the work from being done on the shrimp grounds. Consequently, an observation area with required conditions was selected as close as possible to the capture area.

Underwater television was initially considered but for the study of microfeatures in shallow water, diver observations proved best in this investigation.

Strong tidal currents were not present but there were currents of $\frac{1}{2}$ knot in the capture area.[6]. The observation area[10] was located in a sand regime (greater than 80 per cent sand) whereas the capture area was in a silt clay regime (greater than 50 per cent clay, less than 50 per cent silt). The variations noted must be considered in attempting to estimate the burrowing behaviour of pink shrimp from the data obtained. Another factor to be considered is that most large concentrations of pink shrimp are found in calcareous sand[4] or sand-shell bottoms[5] whereas most of these observations and measurement were obtained on sand-silt-clay bottom.

The only previous description of burrowing methods[1] for *Metapenaeus masterii* generally agrees with the first method described in this paper.

All the burrow measurements here made show that pink shrimp penetrate the bottom so that their dorsal surfaces are just below the surface of the substrate. Williams (1958)[12] found that pink shrimp tend to burrow deepest in sand-shell type bottoms. His laboratory experiments showed that some animals often buried as deep as the bottom of the container (2 in) and he suggests that bottom type may influence burrowing depth.

The nocturnal activity of pink shrimp is generally accepted[7, 8, 9, 3] and the fishery is principally a night fishery.

The results of this study show that activity may be limited even during hours of darkness and indicate that this limited activity may be interrupted. As a generalisation, it appears that adult *P. duorarum* is primarily a fossorial animal.

There are a number of records of pink shrimp being taken in trawls during daylight hours. Eldred (1961)[2] reports personal communications with commercial fishermen that indicate daytime pink shrimp captured under muddy water conditions and on cloudy overcast days. Hildebrand (1955)[5] states that on one occasion daytime fishing produced more pink shrimp than either the preceding or following nights. Similar situations were found by the Fishing Gear Research Unit in Mississippi Sound in spring 1962. Various reasons have been proposed for the phenomenon, including ground swell and low light intensity.

Burrowing as an effective means of trawl escapement has been mentioned[11] and results in this investigation substantiate such statements and may explain spotty catches on the shrimping grounds if burrowing periodicity is intermittent. The use of tickler chains on conventional shrimping gear apparently has little effect on burrowed individuals.

The water circulation system mentioned [12, 1, 3] has been previously noted. There is a possibility that pleopod activity in a cavity below burrowed animals may assist the scaphognathite as a gill pump in establishing the waterflow. The cavity may also provide a reserve space for deeper withdrawal into the burrow under certain conditions of stimulation.

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2. Shrimp Reaction to Electrical Stimulus

by

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IN association with this research into shrimp behaviour, investigations were made to determine the possibility of using electrical aids in harvesting shrimp.

The preliminary experiments were designed to provide basic information for use in more precise and detailed future tests directed toward the development of electrical shrimp trawl gear. They are restricted to electrically stimulated responses of animals burrowed in the sediment. No attempt was made to obtain either galvanotaxis or galvanonarcosis.

The information sought involves two general categories —first the response of shrimp to electrical stimulus, and second, factors associated with an electrical field between electrodes in sea water. In the first category, information required included: (a) Power requirements for positive responses (b) effect of animal-electrode orientation, (c) effect of pulse rate on response.

In the second category, necessary information included the shape, magnitude and characteristics of the electrical field. The data presented here cannot be taken as indicative of absolute threshold values in securing "gear" response but they are considered adequate for determining electrical power requirements for developing shrimp harvesting gear.

Water temperature and salinity in the holding area were approximately equal to that in the capture area. The temperature ranged from 27°C to 31°C and the salinity from 33 to 35 parts per thousand.

An experiment as to the effect of alternating and direct current in producing responses indicated that AC was approximately 75 per cent more effective than DC in water of 33-35 parts per thousand salinity. For this reason all experiments of the preliminary work were conducted with 60-cycle AC current, except in one where AC currents of varying frequencies were compared. The term "pulses" as used here refers to short periods of AC current.

Electrodes used were brass rods, $\frac{1}{8}$-inch in diameter and 24 in long. They were mounted in plastic separators 24 in apart to form a square frame, two sides of which were formed by the electrodes and two sides by the separators (Fig. 3). The electrodes rested on the bottom.

Electrical pulses were delivered to the electrodes through a mechanical circuit breaker (Fig. 4). Pulse rate and input voltage were variable. Voltage drop recorded was that between the electrodes, i.e. a vacuum tube voltmeter was connected directly to the electrodes. Distance between electrodes and power supply was approximately 30 ft. In varying the power used, the input voltage was selected as the parameter and the

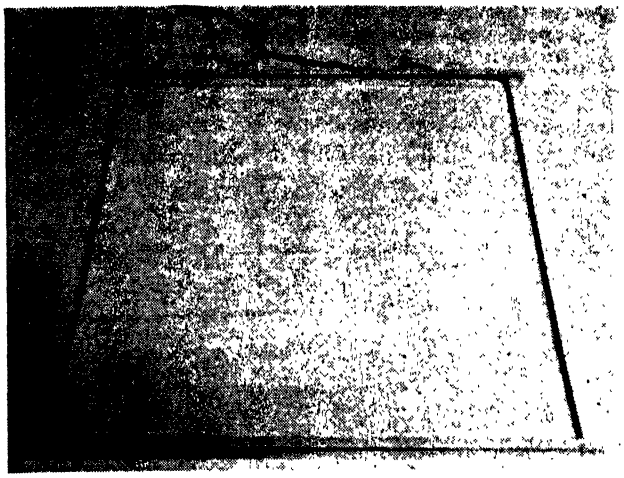

Fig. 3. Electrode frame used in shrimp response and field strength experiments.

current as the dependent variable. This was necessary because salinity and temperature fluctuated through the day, owing to tidal action.

Individual shrimp from the desired size group were removed from the holding tank and allowed to burrow. A diver placed the electrode frame around the burrowed animal in a pre-determined position and signalled the surface operator who activated the pulser. The diver observed the response and reported it to the surface where it was recorded. A positive response was defined as any visible reaction of the animal either weak or strong.

Fig. 4. Mechanical circuit breaker used in preliminary shrimp behaviour experiments.

Electrode orientation

From the first it was apparent that with relatively low power levels, orientation of the shrimp to the electrical field is a very important factor in producing a positive response. The animals responded much more readily if the body axis was perpendicular to the electrodes than if it was parallel to them.

Fig. 5 depicts the method of describing orientation. Table IV is a tabulation of typical responses observed at various shrimp positions in 3 V, 6 V, and 10 V fields. The results indicate that response is directly related to the magnitude of voltage drop across the animal's body.

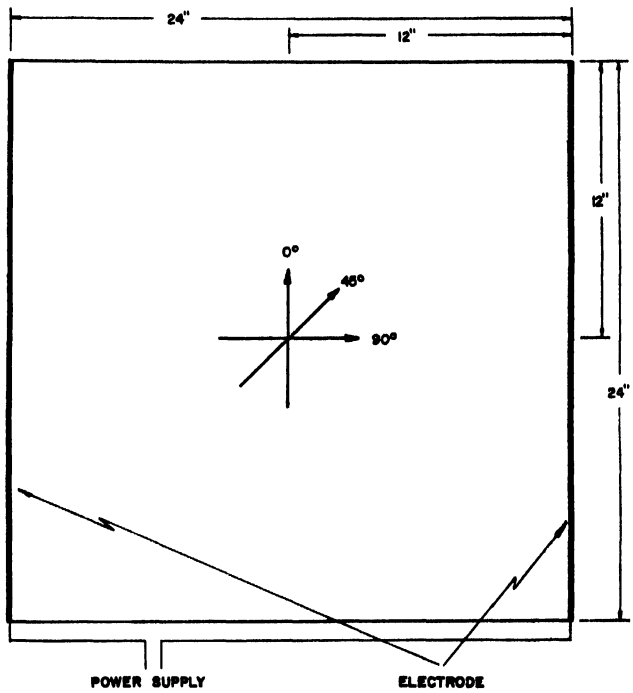

Fig. 5. Method used in identifying shrimp—electrode orientation.

Power requirements

In tests for power requirements the voltage drop across the shrimp body was measured with separate probes. If the animal did not respond the circuit was closed and the voltage drop was measured between head and tail. If the animal responded and consequently vacated its burrow, the circuit was closed and the voltage drop was measured across the empty burrow. In these experiments, in addition to varying the position of the shrimp, its proximity to the electrodes was also varied. Table V summarises results obtained. An approximate threshold level appears to be near 40 millivolts for shrimp in the 120-130 mm size group.

The input power at the electrodes necessary to achieve a voltage drop of 40 millivolts across a distance of 4-5 in in the field is dependent on the orientation of the measurement to the electrodes. Experience to date indicates that 40 millivolts at the electrodes (24 in long and spaced 24 in) will achieve the desired field strength. These experiments will be continued to determine the optimum power level-electrode characteristics for maximum effectiveness.

Effect of pulse rate

Knowledge of maximum effective pulse rate is necessary because the proposed application is with mobile gear.

After tests with pulse rates varying from 1 to 12 per sec, results indicated that a pulse rate of 4 per sec for shrimp in the 120-130 mm size group is near maximum. Faster pulsing produces more rapid, but weaker, contractions. This is apparently because the animal does not have time to relax completely between pulses, which, if true, indicates that a somewhat faster rate should be effective for smaller shrimp and a somewhat slower rate necessary for larger ones. The size-maximum pulse rate relationship will be examined in future experiments.

General observations

The results reported suggest that shrimp response was always either positive or negative. As might be expected, this is not the case. Animals under identical experimental conditions occasionally displayed different reactions. The most common and significant variation was that of magnitude of response. Occasionally very weak responses were observed under experimental conditions that produced strong reactions in the majority of the animals. Also, it was observed that three pulses were usually required to move a shrimp out of its burrow up into the water a distance of 6 to 12 in. However, this response varied from one to six pulses. The apparent progression of response strength exhibited by the atypical animals was independent of field strength (above the threshold level). Because of its progressive nature it is possible that this is due to a physiological condition of the muscle resulting from the moulting process.

Electrical field strength in sea water

The objective of these experiments was to establish, within general limits, the nature of a relatively low power electrical field between electrodes in sea water. As in the shrimp response experiments, information was desired

Table IV—Tabulation of typical shrimp responses at three positions relative to electrodes.

Power volts	Position degrees	Shrimp Number	Response +	Response −
3	0°	1		x
		2		x
		3		x
	45°	1		x
		2		x
		3		x
	90°	1	x	
		2	x	
		3	x	
6	0°	1		x
		2		x
		3		x
	45°	1	x	
		2	x	
		3	x	
	90°	1	x	
		2	x	
		3	x	
10	0°	1		x
		2	x	
		3	x	
	45°	1	x	
		2	x	
		3	x	
	90°	1	x	
		2	x	
		3	x	

Table V—Relationship of shrimp responses to voltage drop across the body (measuring head to tail). Shrimp size 120-130 mm.

Voltage Drop	Response +	Response −
·018		x
·019		x
·024		x
·027		x
·039		x
·042	x	
·050	x	
·057	x	
·059	x	
·064	x	
·072	x	
·078	x	
·095	x	
·110	x	
·133	x	
·138	x	

Fig. 6. Probes used for measuring field strength.

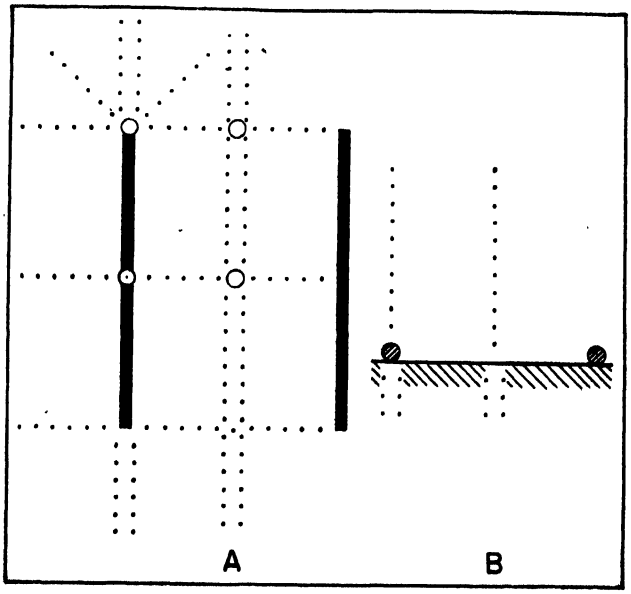

Fig. 7. Pattern used in determining field strength. (A) Measurements in horizontal plane. (B) Measurements in vertical plane. Circles on (A) indicate location of vertical measurements.

for the design of future more precise and specific tests. Factors examined included: determination of the field strength and configuration, the effect of electrode length on field strength and the influence of electrical frequency.

The input voltage at the electrode frame was again selected as the parameter. Field strength measurements were made with a pair of brass probes, $\frac{1}{8}$ inch in diameter and 6 in long (insulated except for end $\frac{1}{2}$ inch) spaced 2 in apart (Fig. 6) and connected to a vacuum tube voltmeter. When measurements were made the probes were always aligned to maximum potential difference at the position being tested. Fig. 7 describes the pattern used for field strength measurements.

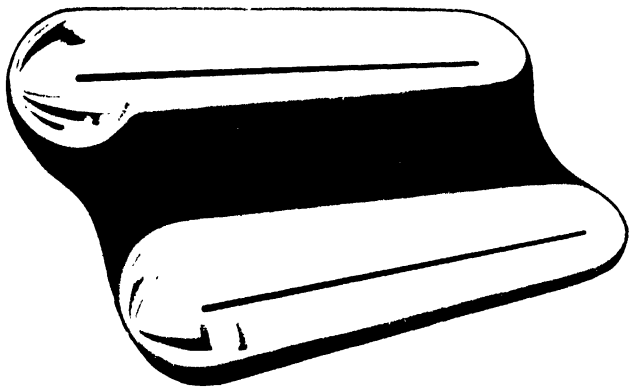

Fig. 8. The general configuration of an electrical field between two electrodes in sea water.

Configuration of electrical field

Fig. 8 depicts the shape of a typical electrical field between electrodes. The field strength is approximately the same below the electrodes (into the sediment) as it is above them (into the water), and a significant field exists immediately ahead of, behind, and outside each electrode; also the magnitude of the field at the power input end is slightly greater than at the opposite end.

It is shown in Fig. 9 that the field strength is directly related to the input voltage, i.e. doubling the input voltage doubles the field strength. It should be noted, however, that the total power requirement for doubling field strength was on the order of four to five times. For example, to produce a 3-V input required 2·4 amps (7·2 W), whereas a level of 6 V required 6 amps (36 W) and a 12-V input required 10 amps (120 W).

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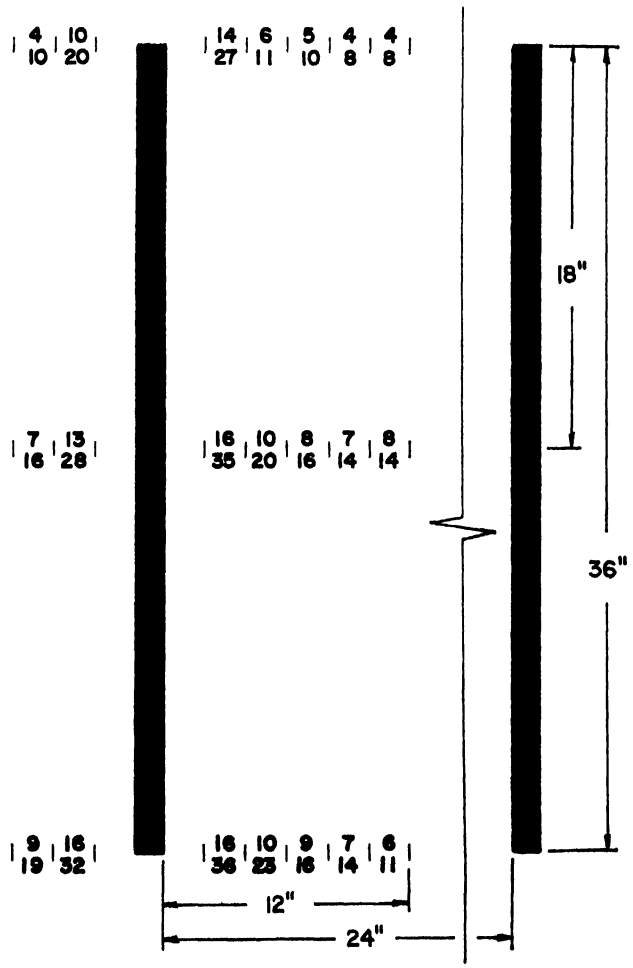

Fig. 9. The relationship between input voltage and field strength (millivolts). Top figure of each pair is with 3-V input and bottom figure with 6-V input.

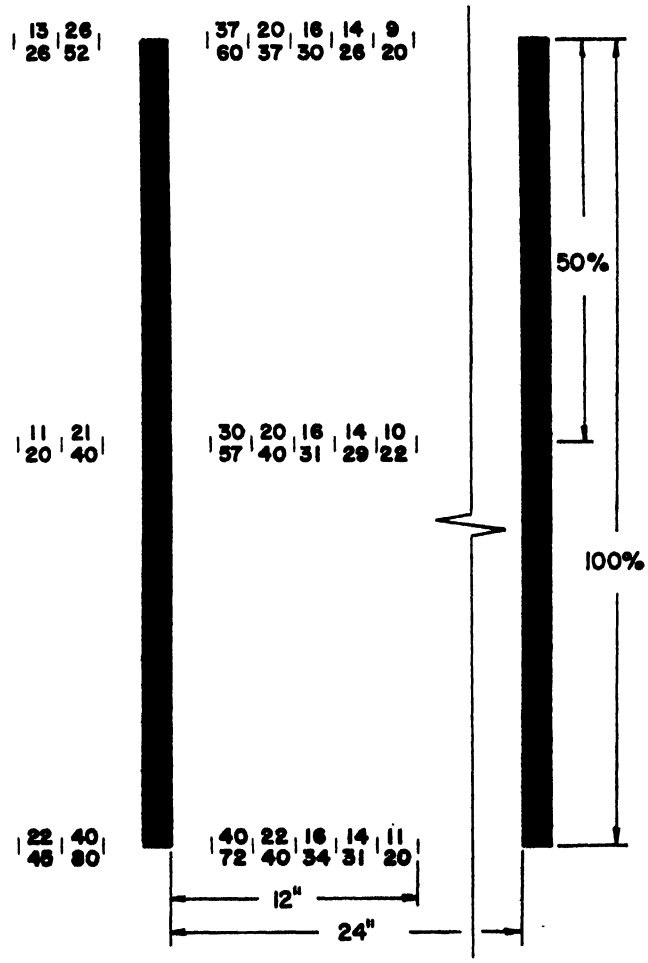

Fig. 10. The relationship between electrode length and field strength (millivolts). Top figure of each pair is with 6 ft electrodes, bottom figure with 3 ft electrodes.

Experimental Dispersion of Chum

Abstract

Most of the studies and experiments with chum have been concerned with the reactions of the fish towards the chum; this paper deals with the movement in the water of the chum itself after spreading. In the "Kaitsuke" fishery in Japan about 100 to 200 kg of whole sardine is scattered twice a day and as this bait disperses horizontally according to the direction and rate of the current, and sinks in relation to its own weight, the handling of bait is an important factor. The experiments conducted showed that the whole sardines sink erratically for the first 5 m depth layer but thereafter have a more regular sinking speed of about 11 cm/sec. Minced sardine sinks at an almost constant rate of 11·5 cm/sec, as compared with sawdust which sinks at 5·7 cm/sec. By repeated scattering the sinking accumulated chum takes a conical shape with an angle at the top of 20-25°. The sinking speed at the top is about 9 cm/sec with a spreading velocity of about 1 m/sec.

Une expérience sur la dispersion de la boëtte

Résumé

Dans plusieurs études et expériences il a été question des réactions des poissons envers la boëtte; la présente communication traite des mouvements dans l'eau de la boëtte même après sa diffusion. Dans la pêche "Kaitsuke" au Japon, à peu près 100 à 200 kilos de sardines hachées sont répandus deux fois par jour et la boëtte s'étale horizontalement suivant la direction et la vitesse du courant, puis coule selon son propre poids. La manipulation de la boëtte est donc un facteur important dans cette pêche. Les expériences conduites ont montré que les sardines entières coulaient de façon erratique pendant les cinq premiers mètres de profondeur, plus régulièrement ensuite à une vitesse de 5·7 cm/sec. En répétant la diffusion, la boëtte accumulée prend, en coulant une forme conique avec un angle au sommet de 20 à 25°. La vitesse de coulage au sommet est de 9 cm/sec avec une vélocité d'étalage d'environ un mètre par seconde.

by

Kentaro Hamashima

Nagasaki Prefectural Fisheries Station

Un experimento sobre la dispersion de raba

Extracto

Casi todos los estudios y experimentos realizados con raba se han limitado a observar las reacciones de los peces hacia ella; esta comunicación trata de su movimiento en el agua después que se ha esparcido. En la pesquera "Kaitsuke" del Japón se emplean dos veces al día de 100 a 200 kg de sardina molida que se dispersa horizontalmente según la dirección y velocidad de la corriente y se hunde según su propio peso. Debido a ello su manipulación reviste importancia. Los experimentos demostraron que las sardinas enteras se hunden caprichosamente los 5 primeros metros, pero después adquieren una velocidad regular de unos 11 cm/seg: las sardinas picadas se hunden a la velocidad casi constante de 11·5 cm/seg en tanto que el aserrín lo hace a 5·7 cm/seg. La raba acumulada adquiere al hundirse una forma cónica con un ánfulo en la parte superior de 20° a 25°. La velocidad de hundimiento en la parte alta es de unos 9 cm/seg y la de esparcimiento de 1 m/seg.

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Electrode length and frequency

To determine the relationship of field strength to electrode length, a series of measurements were made utilising 3-ft and 6-ft electrodes ($\frac{1}{8}$ inch dia). Fig 10 shows the location of each measurement and the value obtained with each electrode length. It is evident that the voltage field strength is inversely proportional to electrode length.

Another factor investigated was the effect of electrical frequency on the magnitude of the voltage field. For this experiment the test probes were positioned, the input voltage was held constant and the frequency was progressively increased using a test oscillator. No variation in field strength due to frequency was found.

Discussion and comment

Past experiments directed toward influencing marine animals with electrical fields have usually had an objective of either galvanotaxis or galvanonarcosis.[17] Also, projections of experimental data to possible commercial scale application have apparently been based on calculations for generating an effective field between a single pair of widely spaced electrodes (Harris 1952; Higman 1956; and others[18, 16]). These projections invariably yield power requirements which are economically unfeasible. The results of experiments reported here, however, indicate that the use of multiple pairs of closely spaced electrodes and achieving a blocking response only affords a potential method of practical application of electricity to shrimp harvesting. In this way, it appears that relatively low levels of electrical power may be utilised to harvest shrimp on a commercial scale.

It is anticipated that successful development of this technique would have application in the present commercial shrimp fishery of the Gulf of Mexico by permitting 24 hr operation. Currently the fishery for pink and brown shrimp is prosecuted largely during hours of darkness, because the shrimp are burrowed during daylight hours. Also it is expected that areas which are presently untrawlable can be made productive through use of electrical power and "off-bottom" trawls. Another possible application is on potential deep-water (200 fathoms) shrimp grounds where irregular but trawlable bottom conditions may significantly limit the effectiveness of conventional gear.

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As with the visual sense, knowledge of the response of fish to taste and odour stimuli is obtained through study of the organs and of experiments in tanks. Fish become immune to the continued stimuli of a certain odour while they do not lose response to a different kind of smell. Observations and experiments show that fish are highly sensitive to taste and smell.

During experiments to ascertain the response, learning and reaction movements, Dr. Uchida of Japan found that some species of minnow responded to a sugar solution of as low as 1/5000th mol, which shows that the sensitivity of fish is 500 times as strong as that of man. Dr. A. Tester of Hawaii, on the other hand, found that yellowfin tuna kept in tanks responded to a solution containing extracts from tuna meat but not to the solution containing extract from anchovy, in spite of the fact that it is known that the tuna feed on anchovy.

Though the chemical components of the various chums used at present to attract fish are well known, it is still not clear which component or combination of components is the active attracting agent. In practice, the materials to be used in fish attraction experiments are extracts of the materials normally used by the fishermen, such as raw meat prepared into juice or powder. Normally some chemicals are added which cloud the water and attract the fish. In mixing specific gravity of the materials must be considered to prevent the material sinking too fast and taking the fish down beyond reach. The materials are therefore usually processed into an emulsion which disperses the fatty substance in the water. Much more study is needed of the known fish-attracting materials which tend to stay suspended for some time and thus keep the fish at the desired depth.

The following materials are used rather extensively in different countries for chumming: (a) fish meal, fish solubles, (b) baked rice, bran, wheat noodles, etc., (c) fish oil, fish extracts, (d) minced fish meat, meat solution, (e) fermented fish and squid, (f) cooked fish offal, (g) fish roe, (h) insect meal.

To these are normally added chemicals such as idol, skatol, aromatic compound, anise oil, sweet wine, etc., to stimulate the olfactory sense of the fish. This type of bait, furthermore, often contains bentnite or rhodamine which accelerates turbidity of the water.

Chumming with chemicals or organic extracts may fall into three distinct physico-chemical kinds: (a) soap, "soapless soap" (ABS) and powder, (b) emulsion, (c) extract solution. To assist in dispersing the material, gas is often used and may include pressurised butane gas or air mixed with water.

Chumming with ground minced fish is practised to a considerable extent in Japan in fishing for mackerel by means of bouke-ami stick-held dip-nets and also with a handline fishery for yellowtail and seabream. The method is called "Kaitsuke" and is widely used near the reefs off the coast.

"Kaitsuke" fishery

About 20 days before actual fishing starts, a bamboo raft is anchored up-tide of the fishing area. The fishing grounds are near the reefs which rise 15-25 m in depths of 45-75 m. About 100-200 kg of sardine bait is scattered twice daily throughout the season which lasts 2 to 2½ months, resulting in from 5 to 7 tons of bait being dispersed. The sardine is minced before chumming.

As the bait disperses according to the direction and rate of tide and current, the handling of the bait is an important factor.

The gear for "Kaitsuke" fishing consists of a handline, lead weight, balance wire, bait bag, snood and hook:

Handline—150-200 m cotton or hemp stiffened by shibu (persimmon juice) or egg white.

Sinkers—500-1,000 g lead.

Balance wire—No. 12-6 brass wire of about 50 cm in length, curved in an arc, one extremity carrying the sinker while the snood is attached to the other end. The hand-line is fastened at about 10 cm from the sinker end.

Bait bag—A square cotton cloth of about 30 cm fastened about 1 m above the balance wire.

Snood—1-1½ m nylon gut (sometimes two snoods are used).

Hook—Various sizes, one per snood.

200-300 g of minced sardine is wrapped in the bait bag. The handline is knotted with a slipknot around the bag. The hook is baited with a sardine and the gear is lowered to near the bottom. By giving the line a smart snap the knot is released; the bag opens and the groundbait disperses. The hook is kept, as far as possible, in the middle of the slowly sinking bait.

Experimental method

Very little is known as to the precise nature of the dispersion of the bait once it has been thrown out so the dispersion and sinking rate of the chum were watched.

The research vessel was anchored where no current occurred at a depth of about 25 m. Four different chumming methods were used and for each type of chum the horizontal dispersion was measured by reference to floats while the relative sinking speed was observed by reference to a Secchi disc or by echo sounding.

The bait and methods used were:

(a) Whole sardine of about 12 cm body length. About 120 fish were thrown at intervals and the dispersion and sinking speeds were recorded by an echo sounder at 10-second intervals so that the dispersion could be accurately measured.

(b) A volume of about 2 litres of minced sardine meat, mixed with an appropriate quantity of sea water, was scattered overboard and its dispersion observed by the same methods.

(c) About 13 kg of wet sawdust was scattered overboard and its dispersion observed for comparison purposes.

(d) At intervals of about 5 sec, half-litre volumes of minced sardine meat were thrown over and the dispersion, especially in midwater, was observed.

During the latter experiments water samples were taken to ascertain its albumin content.

Results obtained

Whole fish—The data obtained by echo sounder is plotted in Fig. 1. The curves obtained are rather irregular, probably due to the shearing motion of the bait while sinking; however, all lines show a more or less identical inclination below the 5 m line which shows that the sinking speed below 5 m was about 11 cm/sec. For the water layer from the surface to 5 m depth the sinking speed would appear to have been as low as 7 cm/sec, which may have been due to the shearing motion on entering the water.

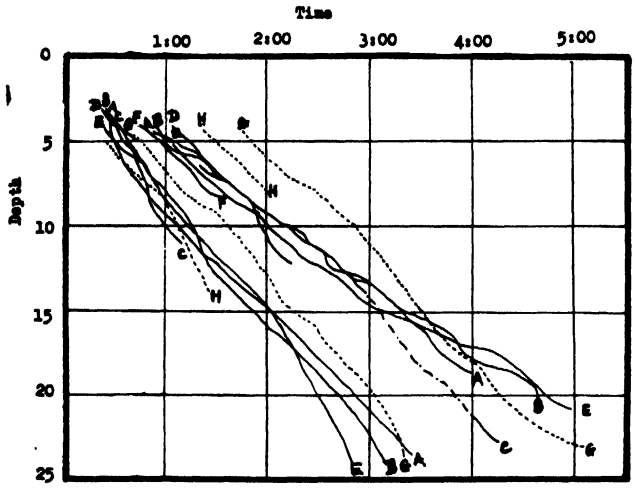

Fig. 1. The lines of upper and lower edge of sinking ground bait by echo-sounding record.

The numerical data of the experiment is given in Tables I and II and shows the sinking speed for every 3 m in the water layer 5 to 23 m. The depth at which the fish arrived at 30-second intervals is given in Table III.

Minced sardine meat—The data observed on the dispersion of minced sardine meat is illustrated in Fig. 1 by the curves marked H and G. A comparison of these tables with the previous ones appears to show the slightly higher sinking speed of 11·5 cm/sec of the minced sardine meat.

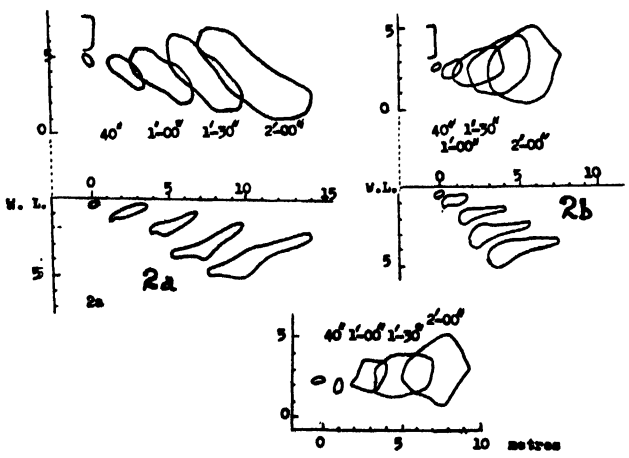

Fig. 2a, b, c. The shape of horizontal and vertical dispersion of sawdust.

Sawdust dispersion—A graphical illustration of the dispersion is given in Fig. 2 (a, b and c). Although the pattern of dispersion changes somewhat according to the condition of scattering, generally the sawdust spread out to a fixed pattern formed about 40 sec after throwing. The sawdust appeared to sink at about 5·7 cm/sec and to spread horizontally at 2·3 cm/sec.

Repetition of scattering—About half a litre of minced sardine meat was scattered every 5 sec. The resultant shape of the sinking mass had a conical form of which the top angle was about 20 to 25°. The sinking speed was about 9 cm/sec at the top while the horizontal spreading velocity was about 1 m/sec.

During these experiments the concentration of albumin in water samples was examined by Ninhydrin colour reaction. The highest concentration was found at 5 m depth at about 10 m distance in down-current direction; this point coincides with the centre of dispersion of the chum at 2 min after scattering (Fig. 3).

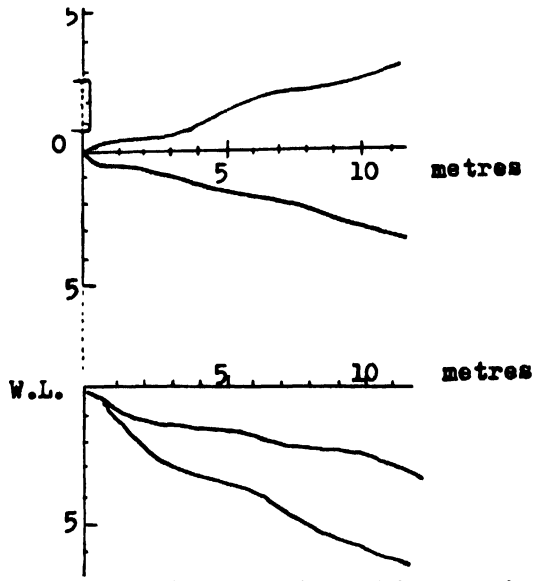

Fig. 3. The shape of horizontal and vertical dispersion of sawdust scattered at 5-sec intervals.

Table I—Sinking time of whole sardine per 3-m layer between 5-23 m depth at upper edge

	5-8 m Sec	8-11 m Sec	11-14 m Sec	14-17 m Sec	17-20 m Sec	20-23 m Sec
A	40	45	45	40	—	—
B	30	50	50	40	50	—
C	40	40	40	—	—	30
D	32	20	45	—	—	—
E	40	45	45	40	50	—
F	40	—	—	—	—	—
Avge time	37	40	45	40	50	30

Table II—Sinking time of whole sardine per 3-m layer between 5-23 m depth at lower edge

	5-8 m Sec	8-11 m Sec	11-14 m Sec	14-17 m Sec	17-20 m Sec	20-23 m Sec
A	18	27	35	30	30	10
B	23	20	20	35	30	30
C	20	20	—	—	—	—
D	15	15	15	20	—	—
E	29	25	30	25	—	—
Avge time	21	21	25	28	30	30

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Evolution de la Pêche à la Lumière dans Les Lacs Africains

Résumé

La pêche à la lumière était pratiquée dans les Lacs africains depuis bien des générations notamment dans le Lac Tanganyika. Cette pêche a toujours été effectuée avec un "carrelet" conique, fait de tulle moustiquaire mais l'introduction de fils de nylon et l'utilisation de lampes à kérosène de 250 bougies a amélioré les captures. En 1954, des armateurs grecs ont introduit la senne tournante méditerranéenne "grigri" dans les Lacs africains. Ces sennes ont des ralingues de liège de 300 m, une chute de 80 m. Les ailes sont construites en nylon de 210 d/9 à 210 d/12, et en mailles de 32 mm tandis que le sac est fait de nylon de 210 d/12 avec mailles de 12 mm (étirées). Les bateaux posent les lumières normalement dans la soirée et au bout de cinq heures, les poissons concentrés dans la zone de lumière sont suffisaèment nombreux pour permettre une opération de la senne. La composition des captures dépend de l'intensité de la lumière et on a constaté qu'en utilisant une intensité de 2000 à 4000 bougies, 70 à 80 pour cent de la capture étaient composés de *stolothrissa* tandis qu'avec 6,000 à 8,000 bougies seulement 50 à 70 pour cent étaient des *stolothrissa*, les autres 30 á 50 pour cent de la capture étant composés de *lates* et *luciolates*.

Evolution of light fishing in the African lakes

Abstract

Light fishing has been conducted on African lakes for many generations, but confined to certain localities. The fishing was formerly only carried out with small dip-nets made of mosquito netting, but the use of nylon netting and kerosene lamps of about 250 candlepower have greatly improved the catches. In 1954 Greek fishing operators introduced the Mediterranean "grigri" purse seine in the lakes. The purse seines are about 300 m long on the floatline by 80 m deep (stretched netting). The wings are constructed of 210 d/9 to 210 d/12, 32 mm mesh, while the bunt is of 210 d/12, 12 mm mesh. The boats normally set the lights out in the evening, and after about five hours the fish is sufficiently attracted for encircling and pursing. The catch composition depends on the intensity of light used and it was found that when using from 2,000 to 4,000 candlepower, 70 to 80 per cent of the catch consisted of *stolothrissa*, while 6,000 to 8,000 candlepower resulted in only 50 to 70 per cent of *stolothrissa*, the other 30 to 50 per cent of the catch being *lates* (perch) and *luciolates*.

Evolucion de la pesca con luces en los lagos Africanos

Extracto

En algunos lugares de los lagos africanos se practica la pesca con luces desde hace muchas generaciones. Antiguamente se empleaban solamente pequeños salabres hechos de red para mosquiteros, pero actualmente se emplean redes de nailon y lámparas de keroseno de 250 bujías y gracias a ello ha mejorado considerablemente la pesca. En 1954 los pescadores griegos introdujeron en los lagos el arte de cerco "grigri" del Mediterráneo. Las redes de cerco tienen unos 300 m de longitud en la relinga de corchos y 80 m de altura (malla estirada). Las pernadas son de 210 d/9 a 210 d/12, malla de 32 mm, en tanto que el saco es de 210 d/12, malla de 12 mm. Normalmente las embarcaciones encienden las luces a la caída de la tarde y unas cinco horas después han atraído peces suficientes para calar los artes. La composición de la captura depende de la intensidad de la luz: cuando se emplean de 2,000 a 4,000 bujías, del 70 al 80 por ciento consiste en *stolothrissa*, con 6,000 a 8,000 bujías su número se reduce a entre el 50 y el 70 por ciento, formándolo el resto *lates* (percas) y *luciolates*.

by
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LA pêche nocturne aux feux, ou à la lumière artificielle, n'a pas échappé à l'astuce des pêcheurs lacustres africains qui la pratiquent depuis des temps immémoriaux. Cette technique particulière est restée toutefois très localisée, car ce genre de pêche n'a pu se généraliser à l'ensemble des grands lacs africains pour deux raisons principales :

(a) la plupart des grands lacs sont eutrophes et la turbidité trop élevée de leurs eaux empêche la pénétration de la lumière qui reste dans ce cas inopérante.

(b) la faune économique de ces lacs peu profonds est surtout représentée par des *Cichlidae* (Tilapia), absolument indifférents à la lumière.

De ce fait, la pêche à la lumière est restée le privilège pratiquement exclusif du Lac Tanganyika, immense mer intérieure de près de 35,000 km2, aux eaux transparentes et profondes colonisées par une faune endémique particulièrement phototrope; il s'agit d'espèces pélagiques représentées par :

—*Stolothrissa Tanganikae*, Clupéide dulcicole (planctonophage), mesurant à la taille adulte 8 cm de long et pesant à l'état frais, 8 grammes environ. Ce

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Table III—Vertical dispersion of whole sardine per 30 sec throw out after 1 min.

	1 min			1 min 30 sec			2 min			2 min 30 sec		
U add L	U*	L*	D*	U	L	D	U	L	D	U	L	D
A	5	9	4	7	12	5	9	15	6	12	18	16
B	5	8·5	3·5	7·4	13	5·6	10	16	6	11·2	19	7·8
C	5	11	6	8	—	—	9·5	—	—	12·2	—	—
D	4	11	7	7	16	9	11·0	—	—	—	—	—
E	5	8	3	7	12	5	9·5	15	5·5	—	12·5	—
Avge			4·7			6·2			5·8			6·9
Dis			0·5			0·8			0·2			0·6

	3 min			3 min 30 sec			4 min					
U and L	U*	L*	D*	U	L	D	U	L	D	U	L	D
A	13	20	7	16	24	8	18·4	—	—	—	—	—
B	13·5	19	5·5	16	—	—	17·0	—	—	—	—	—
C	—	—	—	—	—	—	20·7	—	—	—	—	—
D	—	—	—	—	—	—	—	—	—	—	—	—
E	13	—	—	15·5	—	—	18·0	—	—	—	—	—
Avge			6·2			8			—			—
Dis			0·5			0			—			—

*U=upper edge. L=lower edge D=difference

minuscule poisson constitue 80 à 90 pour cent de l'ensemble des productions du Lac.

Lates microlepis, *L. Mariae* et *L. Angustifrons* (Capitaines d'eau douce), gros voraces dont le poids varie suivant les espèces, de 3 à près de 100 kilos.

—Une sous-espèce, *Luciolates stappersii*, pesant de 150 à 500 grammes.

Ces voraces se capturent en quantités considérables, depuis l'introduction de la pêche industrielle.

La pêche traditionnelle

Jusqu'en 1954, les pêcheurs africains ont utilisé comme matière éclairante, du bois et des roseaux secs. La pêche au *Stolothrissa* est simple; un feu placé à l'avant des pirogues attire et concentre le poisson qui est capturé au moyen de vastes épuisettes. Cette pêche n'est possible que par nuit noire, sans lune.

Cependant, dès 1953-54, une évolution des méthodes ancestrales s'annonce :

—les filets de nylon à mailles de 6 mm de côté, remplacent le tulle moustiquaire utilisé jusqu'alors pour la fabrication des épuisettes;

—les feux de bois ou de roseaux secs font rapidement place aux lampes à pétrole sous pression; il s'agit de lampes du type Coleman, Pétromax ou Tilly, d'une puissance de 250 à 500 bougies. Toutefois, ces lampes dont le réservoir à pétrole (kérosène) se trouve sous le système lumineux, projettent sur l'eau un cône d'ombre entouré d'un large cercle éclairé, contrariant la bonne concentration du poisson. Pour parer à cet inconvénient, on a utilisé avec un succès éclatant, des lampes Standard (Suisse), de 250 bougies seulement et chez lesquelles les rayons lumineux sont projetés directement sur l'eau. La puissance éclairante de ces petites lampes équivaut à celle fournie par une ampoule électrique de 100 watts.

Ces améliorations ont fait passer la production annuelle de la pirogue de 1·5 t à près de 4 t de *Stolothrissa* uniquement. Malgré ces résultats remarquables, on s'aperçut rapidement que la pêche traditionnelle améliorée ne pourrait suffire, à elle seule, à assurer l'exploitation rationnelle des eaux et des poissons tanganyikais, et l'on imagina, dès 1954, l'introduction de pêches industrielles à la senne tournante.

La pêche industrielle

Introduite en 1954 dans la partie Nord du Lac, la pêche industrielle a rapidement fait son chemin; elle est connue aujourd'hui sur l'ensemble du Lac Tanganyika (700 km de long) qui groupe actuellement 15 unités (Usumbura, Uvira, Albertville, Kigoma, M'Pulungu). Elle est le monopole d'armateurs Grecs qui ont reproduit localement leurs unités de pêche méditerranéennes au grigri ou senne tournante. Un maître de pêche européen (Hellène) commande chaque unité, servie en outre par 30 hommes d'équipage recrutés parmi les pêcheurs locaux.

Chaque unité de pêche se compose d'un bateau principal à moteur et de plusieurs annexes non motorisées. Dans cette flottille d'acier, toutes les pièces sont soudées; on n'utilise pas les rivets.

Le bateau senneur varie de 12 à 15 m de long sur 4 à 5 m de large et 1·75 à 2 m de creux. Il est entièrement ponté et équipé d'un moteur diesel marin d'une puissance de 90 à 120 c.v. Un treuil à double poupée est actionné par prise de force sur le moteur.

Le senneur remorque son bateau d'accompagnement (aidant à la relève du filet), de 8 à 9 m de long sur 3 m de

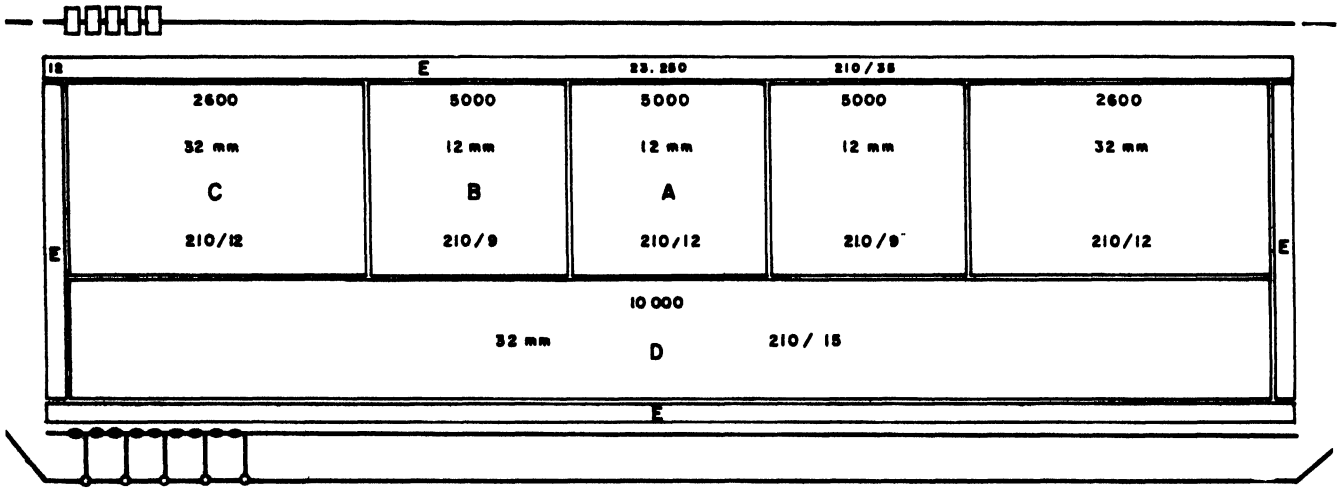

Fig. 1. Schema type d'une senne tournante montée et armée pour la lac Tanganyika.

1. Montage: 20 pour cent de mou dans les filets A et B, 10 pour cent dans C, D et E.
2. Ralingues de flotte et de plombs: 2 x 350 m. Tresse nylon ø 8 mm.
3. Flotteurs: sphériques, en plastique, ø 3", à raison de 8 par mètre dans les ailes et 12 par mètre dans la poche.
4. Plombs: olives de 80 gr; 12 par mètre dans les 30 premiers mètres, à chaque extrémité, et 8 par mètre entre ces 2 extrémités.
5. Anneaux: en acier ø 4", suspendus à des brides de 75 cm, accrochées à la ralingue des plombs. Un anneau tous les 3·50 m, sauf dans la partie centrale, aux points de départ des 2 câbles de fermeture fixés à 2 émerillons espacés de 6 à 8m.
6. Câbles de fermeture: câbles en acier, ø 9 mm. 2 longueurs de 200m, fixées aux émerillons centraux.

large et 1 m de creux; de plus, il traîne 3 ou 4 barques porte-lampes. Ces barques pontées mesurent 4·20 m de long sur 1·45 m de large et 0·65 m de creux: chacune supporte 2 grosses lampes jumelées, à gaz de pétrole (kérosène), de 4,000 à 8,000 bougies, suspendues en porte-à-faux, de façon à surplomber d'un mètre environ, la surface des eaux. L'éclairage de ces lampes équivaut à celui d'ampoules électriques de 500 à 1,000 watts.

Les filets utilisés sont des sennes flottantes, tournantes et coulissantes que l'on emploie en mer, pour la pêche au poisson bleu (Fig. 1).

Ces engins constitués par une énorme nappe rectangulaire en filet, mesurent en moyenne 300 m de long sur 80 à 100 m de chute étirée. La ralingue supérieure porte des flotteurs plus nombreux à hauteur du sac central. La ralingue inférieure lestée de 800 grammes à 1 kilo par mètre, permet l'étalement vertical très rapide du filet. De plus, cette ralingue est garnie d' anneaux métalliques suspendus à 1 m, par des brides espacées de 5 m. Un long câble de fermeture coulisse à travers les anneaux et serre le filet par le bas.

La poche centrale de 50 × 50 m, en fil de nylon n° 9 à 12 et à maille de 6 mm de côté, est prolongée par des ailes de 50 × 50 m, à maille identique en fil No 210 d/6 à 9. Ces ailes sont à leur tour prolongées par des nappes de grandeur variable (50 à 100 m), à maille de 16 mm de côté et en fil de nylon No 210 d/12 à 15. Des nappes semblables à ces dernières, prolongent la chute du filet dont le périmètre est consolidé par une laize à maille de 2 cm, en fil de nylon No 210 d/35.

Le filet se trouve rangé sur la plage arrière du senneur et on le cale en virant par tribord.

A noter que les filets de nylon, sans noeuds, ont été utilisés avec grand succès et sont très appréciés.

Par nuit sans lune, les barques équipées de leurs feux sont ancrées au large, vers 20 h. Apres 4 ou 5 heures d'attente, le poisson s'est concentré sous les lampes et la péche commence. L'ancre est d'abord retirée et la barque est maintenue en place à la rame. Le bateau senneur se rapproche et, tenant compte du vent, mouille rapidement la senne en décrivant un cercle complet autour de la barque porte-lampes, ce qui prend 2 à 3 minutes. Le filet est totalement déployé, en cercle fermé, les deux extrémités du câble de traction coulissant dans les anneaux, sont enroulées autour des poupées du treuil qui entre alors en action; l'opération de coulissage se termine en 10 à 15 minutes, par la fermeture complète du filet par le bas. En fin de manoeuvre, les anneaux et la ralingue plombée se trouvent rassemblés en paquets, contre le bordé, sous les deux chiens de fune (1 bâbord, 1 tribord). Il ne reste plus qu'à haler le filet par les deux bouts, à bord du senneur et de son annexe, pour arriver enfin à la poche et aux poissons qui l'emplissent; ceux-ci sont retirés à l'aide d'épuisettes et mis en caisses sur le pont.

La vindage de la poche terminée, la partie du filet embarquée sur l'annexe repasse en bon ordre sur le senneur, et l'on se trouve prêt à répéter l'opération de pêche autour d'une seconde lampe et ainsi de suite, jusqu'au lever du jour. En général, on arrive â caler trois fois la senne au cours de la même nuit.

Dans la partie Nord du Lac, les captures par nuit de pêche atteignent en moyenne 1·5 tonne de poissons; cependant, dans la partie Sud du Lac, où la couverture biologique est beaucoup plus importante, les productions journalières enregistrées sont de l'ordre de 3 tonnes.

En ce qui concerne les feux, on a constaté que le pourcentage de voraces (gros poissons) augmentait avec l'intensité lumineuse. Des éclairages de 2,000 à 4,000 bougies donnent des prises comprenant 70 à 80 pour cent de *Stolothrissa* et 20 à 30 pour cent de *Lates* et *Luciolates*, tandis que des éclairages de 6,000 à 8,000 bougies assurent des captures de 50 à 70 pour cent de *Stolothrissa* et de 30 à 50 pour cent de *Lates* et *Luciolates*.

La pêche artisanale

Parallèlement au développement de la pêche industrielle, on a recherché le moyen de promouvoir la pêche coutumière traditionnelle, par l'introduction de techniques de pêche plus modernes. Dans la partie Nord du Lac, où les eaux sont généralement calmes, on a mis au point un système de pêche artisanale simple et très avantageux.

L'unité de pêche artisanale se compose de 2 canots métalliques assemblés en catamaran; ces embarcations munies de caissons étanches mesurent 6 m de long sur 85 cm de large et 50 cm de creux; la tôle d'acier a 2 mm d'épaisseur. Ces canots sont accouplés par des fers U boulonnés, les maintenant parallèlement à 2 m d'écartement. Aux quatre coins externes des canots, sont fixés des chiens de funes, largement courbés extérieurement, de façon à atteindre 7 m d'écartement ce qui assure l'ouverture maximum du filet. Cet ensemble est remorqué par un 3ème canot équipé d'un moteur marin interne de 2 cv (Penta-Marinett), ce qui permet d'atteindre de nouvelles zones de pêche situées plus au large (3 à 5 km).

Le catamaran est armé de trois lampes Standard de 500 bougies, ainsi réparties: une lampe au centre de l'ensemble catamaran et une lampe par canot, à l'une des extrémités, de manière à obtenir une large répartition des lumières.

L'unité comprend cinq hommes d'équipage; on compte actuellement 60 de ces unités en activité dans le Nord du Lac.

Le filet-carrelet ou "lift-net", figure une longue poche conique de 5 m de côté comme ouverture, sur 8 m de profondeur, terminée par une poche (sac) de 1 m de côté garnie d'un cadre plombé. La partie conique du filet est en nylon 210 d/6, à maille de 12 mm, étirée (filet sans noeuds) et de 8 mm dans la poche (Fig. 2). Il comprend:

—quatre panneaux droits, rectangulaires de 5 × 3 m, soit 625 mailles sur 375, compte tenu d'un mou de 33 pour cent s'exerçant sur la dimension des mailles étirées. Ces panneaux sont découpés, l'un suivant l'autre, dans une nappe comptant 625 mailles en largeur. Comme ces pièces doivent recevon tout le poids de la traction,

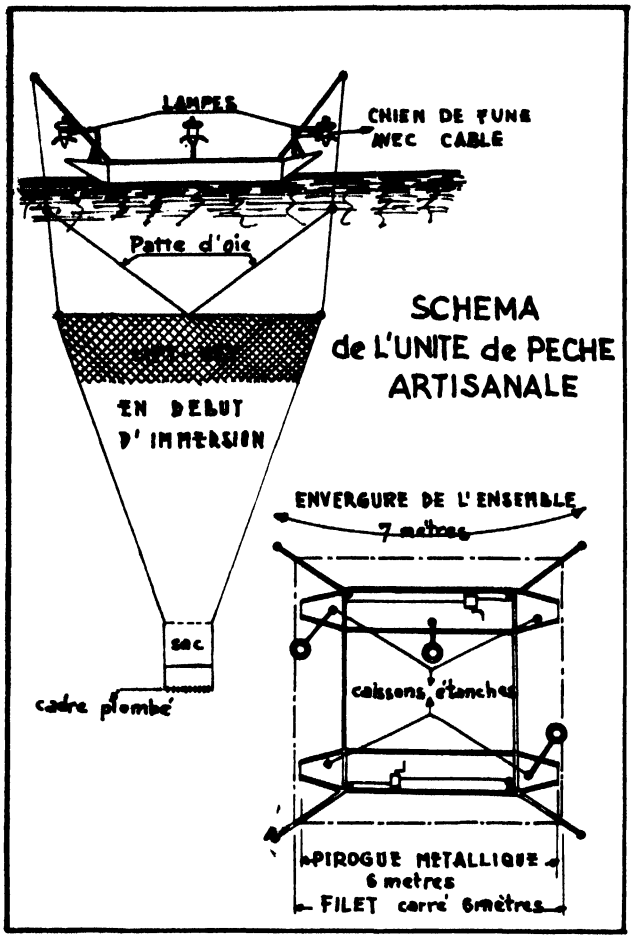

Fig. 2. Schema de l'unité de pêche artisanale.

il est recommandé de les disposer de telle sorte que la traction s'exerce dans le sens du tissage des mailles. Le danger de rupture, provenant des noeuds du filet, est ainsi minimisé.

—quatre panneaux en forme de trapèzes isocèles de 5 m à la grande base (625 mailles), 1 m à la petite base (125 mailles) et 4 m de hauteur, filet armé (500 mailles). Ces trapèzes sont découpés dans une nappe de 500 mailles de largeur, soit la hauteur recherchée. Partant de la grande base (625 mailles), on coupe la nappe en biais, en diminuant de chaque côté d'une maille toutes les deux rangées. On arrive ainsi à laisser 125 mailles pour la petite base.

— cinq panneaux carrés, d'un mètre de côté, à mailles de 4 mm de côté, assemblés de façon à former un sac cubique d'un mètre cube.

Les quatre panneaux rectangulaires qui forment la "gueule" du lift-net sont simplement cousus, côté 375 mailles contre côté 375 mailles. Quatre coutures sont donc nécessaires. Le bord supérieur de la "gueule" est ensuite rabattu et cousu solidement sur une ralingue en nylon câblé de 4 mm; 20 m de ralingue suffisent pour ce travail et l'on coud sur 1 m de ralingue la valeur de 1·50 m de filet étiré ce qui donne le mou désiré.

Les grandes bases des panneaux trapéziformes sont ensuite cousues aux longueurs inférieures des panneaux rectangulaires (625 mailles contre 625 mailles). Les côtés sont également assemblés maille contre maille et figurent ainsi une pyramide tronquée.

Enfin, la poche terminale cubique, composée de cinq panneaux de 1 m2, vient s'ajouter à l'ensemble.

La ralingue de nylon bordant, au sommet, la gueule carrée du lift-net reçoit à chacun de ses quatre coins une patte d'oie qui, en action de pêche, maintient le filet largement ouvert. Chaque patte d'oie est composée de trois brides en nylon câblé de 4 mm, soit une bride verticale de 2·50 m fixée exactement à l'angle de la gueule et deux brides de 3·50 m fixées de part et d'autre de la bride centrale à 2·50 m de distance. Les trois brides se rejoignent au sommet dans un émerillon d'acier, très résistant. Aux quatre émerillons sont attachées les quatre funes de traction, ou cordes de rappel, longues de 50 m, sur lesquelles sont fixés, au préalable, des points de repère tous les 5 ou 10 m, de façon à synchroniser les mouvements lors de la pose et du relevage.

Le fond du lift-net, soit un panneau de 1 m sur 1 m, est lesté extérieurement par un cadre carré en fer à béton, sur lequel on a enfilé 10 kg d'olives de plomb. Ce cadre est relié aux quatre coins extérieurs du fond du sac par des brides en nylon de 50 cm; il assure le mouillage rapide du filet, évite sa torsion et le maintient en position verticale.

La nuit venue, l'unité motorisée gagne le lieu de pêche. Une fois sur place, les lampes sont allumées et le filet immergé directement, le cadre plombé l'entraînant automatiquement en profondeur, jusqu'à bout de course des cordes de traction (30 m environ), l'embarcation étant à la dérive. A signaler ici que le lift-net immergé freine fortement la dérive du catamaran et constitue, en raison de ses mailles fines, une véritable ancre flottante. Dans des conditions de vent assez dures, la dérive n'a jamais excédé 2 ou 3 km. Ceci n'exclut pas que, dans certains cas, vent particulièrement violent et zone très découverte, il faille augmenter le poids du lest et même recourir à une ancre flottante ordinaire qui maintiendra les embarcations dans le vent.

Dès que la concentration du poisson sous les lampes est suffisante (après 3 ou 4 heures), les 2 lampes extérieures sont occultées tandis que la lampe centrale est

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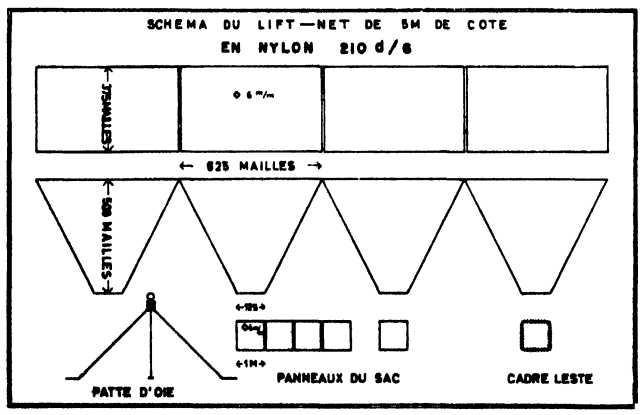

Fig. 3. Pêche artisanale ou "lift net".

Pump Fishing with Light and Electric Current

Abstract

The development by Russian fisheries experts and the success of a new, netless method of kilka fishing in the Caspian Sea, using lights and pumps, indicated such a method might be adaptable to the saury (*Cololobis saira*) fishery. Saury form the basis for an extensive stick-held dip-net fishery, utilising lights to attract the fish, by the Japanese and Russian fleets in the Sea of Okhotsk and adjacent areas. Preliminary experiments commenced in 1957, using the same type of equipment as employed in the Caspian kilka fishery. Although dense concentrations of saury were present during experimental fishing efforts, only a few fish were captured as they easily avoided the suction intake. Then an electro-fishing unit and associated equipment to provide an electrical field near the suction nozzle was constructed. Initial electro-fishing operations were carried out from 28 August to 2 September, 1962, on sparse concentrations of fish. A total of 4·3 tons of saury was caught and the experiments provided an opportunity to make modifications to the equipment and mode of operation. Subsequently, on the night of 2 September, experimental operations were undertaken in dense concentrations of fish. During 1 hour and 25 min of pumping, 4·5 tons of saury were pumped aboard the vessel. The maximum catch rate was 1·5 tons in 9 min of pump operation. This work has indicated the practicability of utilising electricity, in conjunction with lights and pumps, for catching saury. It is quite possible this method may also prove practicable in commercial operations for other species.

by

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Attraction de la lumière et du courant electrique pour le pompage du saury

Résumé

Le succès d'une nouvelle méthode de pêche sans filet pour les kilka (*clupeonella* spp) dans la Mer Caspienne, développée par des technologistes de pêche russes et dans laquelle on utilise des lampes et des pompes, a indiqué que cette méthode pouvait être adaptée à la pêche du saury (*Cololobis saira*). Le saury forme la base d'une pêche extensive au carrelet à perche, avec attraction du poisson par la lumière, pratiquée par les flottes japonaises et russes dans la mer de Okhotsk et les eaux adjacentes. Des expériences préliminaires ont eu lieu en 1957 à l'aide du même type d'équipement que celui employé dans la pêche au kilka (Caspienne). Malgré des concentrations de saury assez denses, pendant la pêche expérimentale peu de poissons furent capturés parce qu'ils s'évadaient aisément de l'orifice de succion. On a alors construit une unité de pêche à l'électricité avec équipement auxiliaire pour produire un champ électrique près de l'orifice ce succion. Les premières opérations de pêche électrique ont été exécutées du 28 août au 2 septembre 1962 sur des concentrations assez claires. Un total de 4,3 t de saury ont été capturés et les expériences ont montré qu'il était opportun de modifier l'équipement et la manière d'opérer. Plus tard, pendant la nuit du 2 septembre, des opérations expérimentales ont été entreprises sur des concentrations denses et pendant 1 h 25 minutes de pompage, 4,5 t de saury furent pompés à bord d'un bateau. Le taux de capture maximum était donc de 1,5 t en une minute d'opération. Ce travail a indiqué la possibilité d'utiliser l'électricité associée à la lumière et aux pompes pour la capture des saury. Il est fort possible que cette méthode se révèle aussi efficace pour la capture d'autres espèces.

Pesca con bombas de la paparda atraida con luces y corrientes electricas

Extracto

El éxito obtenido por los especialistas rusos en el perfeccionamiento de un método para pescar "kilka" con luces y bombas, en vez de redes, en el mar Caspio, hizo creer que podría adaptarse a la pesca de paparda de la especie *Cololobis saira*, que constituye la base de una importante actividad pesquera, con salabres y luces para atraer a los peces, practicada por las flotas japonesa y rusa en el mar de Okhotsk y aguas adyacentes. Los experimentos se iniciaron en 1957 con el mismo material que el empleado en la pesca de kilka en el Caspio. Aunque se observaron densas concentraciones de paparda, sólo se capturaron unos pocos ejemplares, porque evitaban fácilmente el extremo de succión. Se construyó entonces un grupo de electropesca y equipo relacionado, para crear un campo eléctrico junto a la entrada de

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coiffée de manière à n'avoir qu'un jet de lumière plongeant dans l'axe du filet autour duquel se regroupe le poisson en banc compact, au bout de quelques secondes. A ce moment, quatre pêcheurs empoignent chacun leur corde de rappel et halent le filet aussi rapidement que possible. Dans sa remontée, le lift-net dont la gueule est largement ouverte, capture le poisson concentré sous le jet lumineux. Dès que l'engin émerge, il est ramené par dessous les canots, dans l'intervalle libre séparant les deux embarcations, et le lift-net est hissé à bord, où le sac est vidé de son contenu. Mis en caisses, le poisson passe dans le canot à moteur.

Le lift-net est remis immédiatement à l'eau, et la pêche continue, à raison d'un halage tous les quarts d'heure environ; on donne par nuit, de 5 à 10 coups de filet, parfois davantage. A noter que l'occultation des lampes ne dure que le temps de la remontée du filet.

La production atteinte par ces unités artisanales est d'environ 10 fois supérieure à celle des pirogues coutumières, soit de 15 à 40 tonnes de *Stolothrissa*, par an et par unité, suivant la valeur des secteurs de pêche.

Dans le Sud de Lac Tanganyika, les conditions d'exploitation diffèrent; les vents nocturnes y constituent notamment un facteur très limitant, et ces petites unités artisanales ne sont pas suffisamment armées pour faire face à des eaux trop agitées. Aussi, compte tenu de ces conditions particulières, envisage-t-on d'y promouvoir la pêche africaine, par l'introduction d'unités réduites de pêche à la senne tournante. La vulgarisation de cette technique de prédilection, combinée à l'emploi judicieux des lumières conduira à l'exploitation rationnelle du Lac Tanganyika.

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succión. Las actividades iniciales de electropesca se realizaron del 28 de agosto al 2 de septiembre de 1962 en concentraciones poco densas de peces. Se capturó un total de 4,3 tons. de paparda y el experimento facilitó una oportunidad para hacer modificaciones en el material y en la manera de emplearlo. Posteriormente, en la noche del 2 de septiembre, se realizaron experimentos en concentraciones muy densas de peces. En 1 hora y 25 min. se bombearon 4,5 tons. de paparda. La velocidad máxima de captura fue de 1,5 tons. en 9 min. Estos resultados indican que es práctico utilizar la electricidad, en combinación con luces y bombas, para pescar paparda. También es posible que este método resulte ser factible en la pesca industrial de otras especies.

A NEW method of fishing for Caspian kilka by pumps and underwater lights, was established in 1954. By 1956, eleven ships were equipped with pumps and their catch totalled 4,500 tons. Now a growing fleet of pump-fishing vessels catch over 100,000 tons of kilka.

The success of this new method led to experiments for determining its efficiency in the saury (*Cololobis saira*) fishery in the Sea of Okhotsk and adjacent areas. Saury form the basis of a large fishery undertaken by Japanese and U.S.S.R. fishermen using stick-held dip-nets together with electric lamps.

Experimental fishing was initiated in 1957. Although dense concentrations of saury were observed, these active fish easily avoided the suction of the nozzle, and only an occasional fish was captured.

It was decided that an electrical field would be required in addition to the pumps and lights. Accordingly a low voltage direct current unit was constructed and installed aboard the medium-size trawler (SRT) *Izumrud* (Fig. 1).

The unit consisted of an electric-drive fish pump (RB-150), suction equipment, hoses, non-return valve and water separator, together with DC generator. The cathodes consisted of two steel pipes suspended on booms near the bow and stern of the vessel; the suction nozzle, insulated on the outside, served as the anode. Electrical current to the electrodes was supplied through a rubber-insulated cable. The vessel was also equipped with the same type of lighting system for attracting saury that is commonly used in the stick-held dip-net fishery.

Saury were attracted to the lights in the usual way, except that the customary red lamps were replaced with a 500 W focusing red light source in a diffusion dome lamp. This lamp was suspended at a height of 0·5—1 m above the water surface, directly over the suction nozzle. Saury, which had gathered in the large zone illuminated by the customary blue lamps, were directed to the zone under the red light by switching off the blue lights consecutively till all other lights were off. The pump was started, and 5 or 10 sec after the red light had been switched on, current was supplied to the electrodes to make the concentration of saury denser and to direct the fish to the suction nozzle. When the current was switched on the saury got extremely excited, rushed swiftly to the suction nozzle (anode) and were caught.

During these experiments, various modifications were necessary before the gear functioned properly. Due to rough seas, the suction nozzle was frequently lifted out of the water, but this was remedied by suspending it on floats, and a weight attached to the lifting cable to help

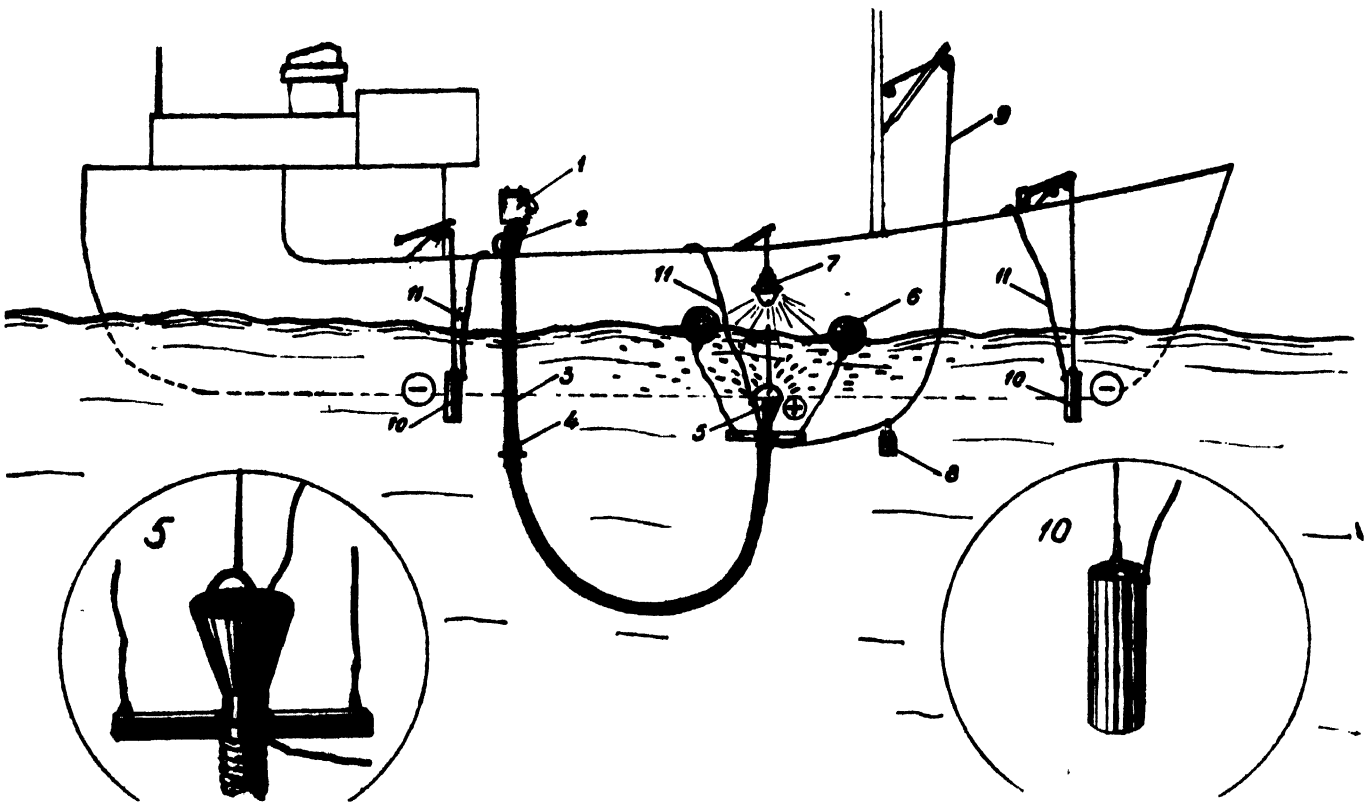

Fig. 1. Medium size trawler (SRT) Izumrud *used in electro-pumping experiments 1. Water separator. 2. Pump RB-150. 3. Suction hoses. 4. Non-return valve. 5. Nozzle (anode). 6. Buoy. 7. Focusing light source (red). 8. Balance weight. 9. Lifting cable. 10. Cathodes. 11. Electrical cable.*

keep the equipment stable and submerged. It was noticed that saury, rushing towards the suction nozzle under the influence of the electric current, sometimes passed by the nozzle and out of the electric field, thus eluding capture. This was remedied by connecting a metal pin to the anode in such a way that it was fixed over the centre of the plane of the suction nozzle.

From 28 August to 2 September, 1962, only sparse concentrations of saury were found. The main purpose then, however, was to improve fishing techniques. Even so, 4,300 kg of saury were captured. On the night of 2 September, dense concentrations of saury were located, and a total of 4·5 tons was taken during the pumping operation which lasted only 1 hr 25 min. The maximum catch rate was 1·5 tons in 9 min of operation. The entire catch was graded first-quality by the cannery.

These initial experiments indicate that netless fishing for saury with combined pumps, lights and electrical current is practicable. Future efforts should be directed at increasing catch rates by extending the zone of the attracting effect of the electric current with minimum expenditure of energy through use of impulses of short duration and optimum frequency. It is also likely that this type of netless fishing with combined light attraction and electrotaxis may prove to be practicable for other species of fish.

Discussion on Fish Behaviour

Mr. Blaxter (U.K.) Rapporteur: In the last Congress discussions on fish behaviour followed three distinct lines; (1) distribution—the factors in environment which concentrate fish; (2) use of artificial lights for attracting fish, and the vision of fish, and (3) electrical fishing. In that 1957 Congress two rapporteurs emphasised the need for much more work on behaviour, and this has been done. Work on artificial light stimulae, especially combined with electrical fishing, has continued, and there have been interesting developments in electrical fishing in connection with trawling. New developments concern the use of an air bubble "curtain" at sea, aquarium experiments on fish behaviour and new techniques and improved old ones for observing fish in the sea. Unlike in 1957 there is no detailed report of either the horizontal or vertical distribution of fish. However, by diving and underwater television of shrimps by day and night, Fuss found he could correlate burrowing habits by day and greater activity by night with poor and good catches respectively. Nishimura's paper shows that changes in vertical distribution of tuna during day and night were related to light intensity and the presence of prey.

Three levels of research are dealt with in the papers: (1) Basic experimental work in aquaria; (2) Experimental work at sea; (3) Comparative fishing experiments to test ideas on behaviour and new fishing techniques.

(1) On the first point two authors mention the disadvantages of tank experiments—the effect of capture on the fish and the confined surroundings, etc. These tank experiments seem of great value when part of a wider programme, but their expense can be a great drawback.

Blaxter, Parrish and Dickson, after experiments on herring, ground fish and other species to test their reactions to driftnets and trawls, reached the main conclusion in relation to driftnets that vision was very important to herring in avoiding such nets, and it was possible to measure the light intensity when herring started to pass into nets which they would avoid in daylight. Light measurements at sea during the Scottish summer herring fishery showed that the light was above the threshold during a greater part of the fishing period, thus suggesting that driftnet fishing is then relatively inefficient. Of all nets tested, monofilament nylon had the highest threshold, aquarium herring swimming into it in full daylight. This relative invisibility of polyamide monofilament fibre, especially of small diameter, was confirmed by Steinberg and also by Tran-Van-Tri and Ha-Khac-Chu and by Shimozaki. In contrast Mr. Watson from Kenya found that low visibility of driftnets was not of importance. Presumably this factor will vary in importance in different species, and with their physiological state as well as other factors.

As to the herding properties of different parts of towed fishing gear—reaction distance being usually less than 2 m—the speed of tow is of great importance—over about three knots the herding drops markedly. While trawling speed may need to be increased to prevent fish escaping, if it is increased too far any value of herding by the peripheral points of the gear may be lost, because the fish have insufficient time to react. As with stationary nets, visibility is important and the herding reaction is reduced to a very low level at night. Underwater lights, however, although providing visual stimulae, were found to be ineffective at night in herding herring or cod, these fish being very inactive at night in these particular experiments.

Chapman's experiments with sound sources of low frequency showed that herring and cod could keep away from such sources, but probably not by direct avoidance.

(2) Recent techniques for observing fish behaviour at sea are underwater television for observing prawns (Fuss), television on trawls (Kreutzer), cameras (Blaxter, Parrish and Dickson), diving (Fuss), underwater viewing ports (Magnuson) and submarines.

Of greatest interest is the development of echo sounders, especially of the netzsonde described by Mohr and of the high resolution Sector Scanner by Tucker and Welsby. Mohr shows the value of the netzsonde for observing herring and other species in the mouth of a midwater trawl. His main conclusions are important and worthy of study in the original paper. The disadvantage of the netzsonde is presumably its inability to assess movement of fish *over* the headline. This suggests the need for netzsonde in tandem—one pointing down and one pointing up—when observing fish behaviour. The fact that towing speed appeared optimal for herring between 3·5 and 4·2 knots as suggested by Schärfe is interesting in relation to the observation that herding became reduced above about three knots in tanks.

Tucker and Welsby have pointed the way to a new and valuable development of echo sounding for tank and sea work—the high resolution and PPI presentation of their scanning sounder permitting the following of the movements of individual fish. This might well provide a breakthrough in behaviour studies where fish must be observed at a distance or in darkness. However, Nishimura, using a more conventional sounder, was able to follow the diurnal distribution of tuna and to estimate their "maximum speed under normal conditions". Lenier's report on species recognition by echo sounder—

and important aid to fishermen—was based, at least to some extent, on behaviour.

Cameras equipped with flash on trawls, and television on trawls in shallow water without artificial lights have shown how fish remain in front of a groundrope during towing. Some may swim forwards and out of the net depending, presumably, on the speed of the tow. While fish are swimming in an orientated manner in front of groundropes in good light conditions, at night this orientation becomes reduced or lost as the use of vision decreases. This confirms the importance of vision in reactions to nets found in the tank experiments. Clearly it is not satisfactory to use underwater television at night because of the artificial lighting required but day and night use of netzsonde would be valuable.

(3) Observation by comparative fishing demands much time and patience and may give very little certainty in results as pointed out by Dickson. They can, however, be planned in conjunction with more basic experimental work so that worthwhile results may be obtained. An open question is how the Vigneron-Dahl sweep gear works. Further trials by day and night, with and without sweeps, especially using a net of fixed mouth aperture, are needed to assess the sweep effect. It is not at all clear at present how the stimuli produced by the sweeps might be effective by night and how important is the length of the sweeps. How do sweeps alter the shape of the mouth of the net? Do long sweeps permit fish to settle after the boards have passed, and what is the sphere of influence and effect of the boards themselves? These are serious gaps in our present knowledge.

Variations of mesh size and shape as mentioned by Schärfe suggested that nets with four seams gave a shape of mesh which may have prevented escape of fish within the net. Dickson used small otter trawls with different mesh sizes in the front, and found that a small mesh produced better catches and seemed to prevent the escape of *larger* fish. Perhaps these were held within the net after making a spurt from farther back. This raises the question of the crowding of fish within and in front of the codend. What influence do fish have on each other at this point—as they become more and more crowded? Do they suddenly "burst" outwards? The need for a small mesh net at this position, which would vary with fish density, species and size is essential. Equally, the importance of the taper of the net both on fish behaviour and pressure stimuli produced by the net is obvious.

Perhaps the highlight of this section, and even of Congress as a whole, is Kreutzer's paper in which he describes the use of pulsed DC electric fields around the mouth of a trawl. He estimates that only 10-60 per cent of fish in the path of a trawl are normally caught by conventional gear. By the use of electrodes on the mouth of a trawl and extensive comparative fishing trials on mv *Delaware*, it was shown that catches of fish might be increased from 100-500 per cent depending on the species and fishing conditions. Fish near the mouth were prevented from escape around the periphery and through the meshes, as a result of electronarcosis. This technique would seem to have a bright future for both bottom and midwater trawls, and, as suggested by Kreutzer, for enticing fish from rough ground.

But his technique, if developed, will not be the panacea for all fish behaviour problems. The study of behaviour in relation to the peripheral parts of the gear, in the leading and herding into the net mouth and the prevention of premature escape reactions and early warning of the nets approach, will be still necessary.

One advantage of electrical fishing is its selective effect on large fish, but the danger in this new method of catching many undersized fish may be serious from the conservation point of view. Dethloff has made a very detailed study of the effects of lights, electrical fields and pumping on Newfoundland herring, which should lead to developments in that area. Other methods described are by Nikonorov of light attraction electrical field pumping technique for saury fishing and by Wathne whereby prawns may be made to leave their burrows in daylight through the use of low power electric fields. Collart reports methods of encircling fish by a purse seine after they have been attracted to lights.

A quite novel method described by Smith is the use of air-bubble "curtains" by pumping air through a perforated pipe dragged along the bottom. This guides herring towards stake nets and weirs and seems to have been highly successful.

In summary, it is valuable to consider how the main senses are involved in the reaction of fish to gear. In this way, lines of future work become clearer. Vision has been especially emphasised and confirmed in tank and sea experiments. The low visibility of monofilament fibres in driftnets is also stressed and vision is further involved also in the reaction to air-bubble curtains and in the reaction of tuna to bait. Further work on catches of trawls using different types and lengths of sweeps and different boards and herding devices, by day *and night*, is badly needed. Observations by netzsonde, camera, and by diving, or the use of towed bodies or submarine need to be developed.

More information is required on the importance of sound and other mechanical stimuli in reaction to gear. While Chapman has presented some theoretical evidence that fish are unlikely to perceive, with any exactness, the direction of low frequency sound sources, Freytag mentions experiments where gurnards seem to have been attracted by sounds from a loudspeaker. Freytag also describes the mechanism of sound production in fish and its importance. A wide field of investigation is open here. For instance, herring seem to produce a whistling noise of 6-7 kcs as a school veers. The possible value of playing back sounds to fish in order to attract them has obvious possibilities.

The identification of fish species by their sound spectra, described by Hashimoto and Maniwa, could be of the greatest value.

Finally, chemical or olfactory stimulation is of special importance in bait fishing. Magnuson shows that the smell, as well as the sight of bait in tuna fishing, needs consideration.

Problems of behaviour necessitate the development of new techniques, and more manpower and facilities may become allotted to this work as advocated by von Brandt. I suggest the following developments for early prosecution in order of importance:—

(1) Development of electrical fishing in association with trawls; (2) development of a monofilament gillnet of low visibility which can be easily stowed (not bulky), does not damage fish and is easily handled; (3) the use in more basic behaviour studies of trawls with a fixed mouth opening and the comparison of day and night fishing with different types of herding device.

Dr. Cole (U.K.): I would like to make some general remarks to supplement a very able summary. Fish behaviour is an extremely complex subject and requires years and years of study before we can even attempt to provide full knowledge of particular species that will enable gear to be devised for satisfactorily catching them. The influences that affect fish behaviour must be considered species by species, and when we have settled on one particular species for study its behaviour will be found to differ with age, physiological condition, nutritional state, stage of maturity, hormone balance,

and so on. There is temperature, and we have an indication last winter of its importance in affecting fish behaviour. A great deal of work had been done on cod in the Arctic in relation to its reaction to temperature. This is very important, especially in areas where there is a strong flow of cold water. It is important to the fisherman so that he can work more efficiently. The thermocline is important in relation to the tuna. Also important are salinity, oxygen content, currents and their direction—and this is not a simple matter because there are internal waves, eddies and tidal cycles. Turbidity and light and bottom topography may be related to currents—all these have to be considered. There is the association of species—what species are found together—whether they are predators. Noise—that produced by gear or the ship, and probably even the noise of the fish themselves—all these can affect behaviour. Pressure, feeding, trace elements, smell—this catalogue is not even a complete one, and finally the rapporteur had suggested that fish might even learn how to avoid gear! I cite these points not to show that progress is impossible but to indicate that we cannot make any simple statement about any particular species.

Having mentioned these points I would like to comment on the methods by which progress may be obtained. First, I would like to make a strong plea for precise laboratory experiments isolating a single stimuli and studying its effect. It seems to me that work of this kind is basic and essential. Of course it is not easy to organise because it requires considerable facilities in the way of tanks and environmental control and instrumentation, and these are somewhat expensive. In the second place there are methods of direct and indirect observation. Most of these have been mentioned. I feel that after our experience with frogmen these methods have distinct limitations—limitations of depth of working—speed at which one wishes to tow the trawl and, further, most frogmen observations of trawling gear have taken place in situations that are not particularly fishing situations. Bodies which can be mounted, such as television cameras, and echo sounders, undoubtedly have a large place in investigation. We at Lowestoft are very interested in the possibilities of using echo sounders on the gear—not merely netzsondes. We are thinking in terms of multiple transducers put inside the gear in various places observing in several directions and bringing in results over a number of recorders or in a series on the same recorder. Sector scanning, too, can become important. Comparative fishing experiments, I myself view with some caution because it seems to me that to provide significant answers it is necessary to conduct very strong controls in general, because the normal variation that one notices from consecutive hauls on the same ground are considerable. It is very difficult indeed in comparative fishing experiments to isolate a single variable and subject it to tests. Most of the alterations that are made in the gear, the bridles and the doors are likely to have other and multiple effects, and then it is very difficult to know what you are examining and then to assess your results. After mentioning all these difficulties, however, I hope that in future years we shall be able to make substantial progress along a large number of lines.

Mr. Dennis Roberts (U.K.): I would like to stress that fish behaviour is one of the most important things for the trawlerman to know about. There are two things we can do—go after fish, or attract the fish to ourselves. In relation to the diurnal movement of the fish, can anybody devise some way of attracting the fish down to the trawl instead of working to get the trawl up after the fish?

Mr. V. T. Hinds (U.K.): Our problem at Aden is with phosphorescence when fishing on moonless nights. After we have detected a school of fish and endeavoured to encircle it with a purse seine, the net itself disturbs the phosphorescence so that the fish make for the gap where there is no phosphorescence and escape before the ring can be closed. In midwater trawling at night the gear disturbs the phosphorescence and scares the fish away. What is the remedy?

Mr. B. Petrich (U.S.A.): When we fish at night time we use a flashing submarine light and that keeps the fish away from the opening. We also, some years ago, used air bubbles with partial success.

Prof. Diaz de Espada (Spain): In tuna fishing one problem is that the fish escape from the lower part of the net before we can close the purse seine. I understand this is similar to what happens in whaling. I understand that whales dive to great depths and the practice has been developed of using a special noise to bring them back to the surface. Can any similar practice be evolved to frighten the fish away from the bottom?

Mr. Harper-Gow: My understanding is that the whale frightener was devised not to bring the whale up, but to stop it from going down by frightening it and making it run. When a whale runs it doesn't go very deep and has to come up to breathe.

Dr. W. M. Chapman (U.S.A.): I alluded this morning to the effect of the thermocline on tuna behaviour, and it might be useful to comment at greater length now. There has been one series of observations made with adequate scientific gear in the Eastern Pacific during the past six months, and this series of data, accumulated from three vessels on which there were thermographs and adequate operators to interpret the results, has proved interesting. The data cover about 225 sets of nets. Of the sets which were in water where the thermocline was not more than 20 fm deep between 60 and 80 per cent were successful. Of those sets where the thermocline was deeper than 20 fm but less than 25 fm, the number of successful sets was 37 per cent—if my memory is correct. Where the thermocline was between 30 and 35 fm the percentage of success fell to 26 per cent. There was a sharp drop in the success of the sets after a rather small difference in the depth of the thermocline. There has not been any more positive data on this subject as yet. We have also quite a good record of the variation of the thermocline depth in the area directly off the Californian Coast where the Navy, for their own purposes, keep a record. There also exist in that area and in the season an active purse seining fishery for bluefin tuna. When the scientists were working over this data from last year's catch they found that 80 per cent of the successful sets for bluefin in the Californian waters had been made in an area about three miles long each side and within an area where there was a persistent shallow thermocline during that period. There is a great deal of purse seining in adjacent areas extending over 40 or 50 miles, but the percentage of successful sets is very small.

Turning to the influence of sound on fish they do use sound to scare tuna in the course of setting the net. They use what they call cherry bombs—a small explosive that the men threw into the water when the net is being closed, and during the pursing period. This is done for the purpose of frightening the tuna away from the opening, and it is highly successful—although sometimes they will come right through the sound. Experimentation has been done in Hawaii with a view to obtaining a pure record of the sounds made by skipjack tuna during schooling and feeding with a view to playing them back so as to attract the skipjack. But this so far has not been successful. The skipjack tuna is very difficult to purse seine because they move very actively, and their first instinct is to

go right down quickly. This is in general true of tuna of all varieties—they are very quick to sound.

Mr. B. Petrich (U.S.A.): A recent development has been to improve those cherry bombs by giving them a delayed action so that they sink and explode lower down. The purpose of this is to make them explode below the tuna and keep them up and stop them diving. This has been a complete success.

Mr. J. Dethloff (Germany): Is it known when the tuna try to escape what is the diameter of the net just being pursed, or at what diameter does the tuna start to escape? Secondly, will they start diving vertically or round the edges of the net? I know tunny are affected by an electrical field of an insulated cable at a distance of about 30 ft.

Dr. W. M. Chapman (U.S.A.): The tuna net is about 600 fm long and the net is set in a wide circle so that with extension lines it will run more than 900 to 1,000 fm. The tuna are perfectly capable of escaping from that maximum entrance until the ring is hauled. My own observations are that the tuna dive vertically and instantaneously. The difficulty of Mr. Dethloff's method is that the length of reach of the pulsed DC current in salt water is such that it will not reach far enough out in such a large diameter as the net was enclosing. The method would not much affect purse seining.

Mr. R. Balls (U.K.): How much has the change in the abundance of North Sea herring affected its behaviour, and, secondly, how is the pressure of new methods of catching and the interference of trawls affecting the herring's behaviour?

Dr. G. Freytag (Germany): to supplement his paper on the bioacoustical detection of fish and the paper by Hashimoto and Maniwa on the frequency analysis of marine sounds, played recordings made from fish and other marine noises as referred to in those papers. They revealed, he said, possibilities of influencing fish by attraction or repulsion as well as by operating against predators. Congress listened to the tapes with much interest because of their practical demonstration of the points made.

Dr. H. Levy (Morocco): In Morocco we experimented with colour in our net material. We found the fish behaviour quite marked. With nylon you can choose your own colour, and in Morocco we tried out brown, then blue, and then pink, and the fishermen confirmed that pink does not frighten the fish. Some people used green and white, but brown, blue and black proved to be failures. Has any detailed study been done on the point of fish behaviour when faced with colour?

Mr. Harper-Gow (U.K.): In relation to electrical fishing, I am under the impression that the difficulty of using electrical fishing in a moving trawl is that whilst the effect on the fish actually in the field can be determined, fish on the extremes of the field are inclined to be frightened away.

Dr. C. O. Kreutzer (U.S.A.): We tried to find out whether fish were scared away at the fringe of the effect. For this purpose we interrupted the experiments. We left the field on for two seconds and then cut it off for 10 seconds so that the fish could assemble. We then compared this with continuous current and there was no difference whatsoever. We think we have an explanation for this but it is difficult to explain.

Mr. A. W. Anderson (U.S.A.): Can you say anything about the directional perception of sound in fish? Can fish detect where the sound comes from and swim towards it?

Dr. Freytag (Germany): We experimented on fish at Hawaii in a tank with a loudspeaker at about 50 cm or so from the fish. The fish immediately turned towards the sound and then turned left or right, and then began to lose interest. We think that their lack of interest was due to the lack of any optical stimuli associated with the sound and which they expected to find in association with that sound, as indicating the presence of another of their species.

Mr. Anderson: Can Mr. Welsby say anything about the effect of sector scanning for use in fish behaviour studies?

Mr. V. G. Welsby (U.K.): Very briefly I can say we have carried out experiments in tanks which have shown that experimental sector scanning equipment of this type is capable of giving information concerning the behaviour of fish which would be very difficult to obtain in any other way. I am quite convinced that this pulse electronic scanning technique which we have developed is something which will in future provide an extremely valuable research instrument for studying fish behaviour. One thing that comes to my mind is that I have seen a demonstration in which it was required to find how fish behaved in the dark when an experimental net was being towed. Visual methods cannot be used in the dark and any attempt to introduce light into the vicinity of the net will alter the surroundings and the fish behaviour, and as far as I know, the use of ultrasonic, and particularly of an electronic scanning device of sufficiently high resolution required to watch the movements of individual fish is the only way in which the behaviour of individual fish can be watched in complete darkness.

Mr. E. Bayagbona (Nigeria): The sending of electrical impulses through the footrope of the trawl—would not that run foul of fishery regulations, and also create a lot of imbalance to the fauna of the benthos?

Dr. Kreutzer (U.S.A.): We have studied this problem very thoroughly. We think that with an electrical trawl we are capable of chasing away all the small fish and catching only the large fish, and we even hope that we can select the species. That sounds like science fiction, but we have every good reason to believe so, and we have scheduled some new tests on the Fish and Wild Life Service vessel, *Delaware*, for September to prove these ideas. On our first test we saw it quite clearly that we had more large fish, but we did not have enough personnel to evaluate the knowledge and measure each individual fish, but the fact that only large fish are influenced by the current has been known since the early 1920's.

Mr. K. C. Rowe (U.K.): While the biologists say it may take many years before any progress is made in scientific research into fish behaviour, I would remind them that over 90 per cent of our nation's fish is landed by deep-sea otter trawling. If they intend to play any real part in the progress of our fishing industry in its present form I would suggest they consider a greater degree of specialisation in their work and the spending of a proper percentage of their time on otter trawl gear and the main species of fish that are caught by this method. Progress in trawling gear through scientific research has been practically nil. Advance has only been made by comparative fishing experiments by commercial trawlers. Last year some British trawlers working the Faroe grounds for haddocks found that if they raised the headline at the expense of a little spread, and if they let their wings fly as is the custom over rough ground, they caught more haddocks and fewer codlings. These trawls were rigged somewhat similar to the French type of trawl used experimentally at Aberdeen. Those boats which later fished for whiting in other areas adopted a similar rig but kept to the old style of smaller mesh in the squares and baitings, and thus provided a fairly successful year-round trawl. I suggest co-operation between the scientists and the practical fishing interests to determine: (1) the right distance between the otter boards in ratio to the right cable length, having regard to the power available and to the species sought; (2) to solve the maximum headline height required, having regard to the density height of various species of fish when meeting the trawl.

Prospective Developments in the Harvesting of Marine Fishes

Abstract

To utilise fully the protein resources of the oceans, man must devise better methods to harvest the great diversity of marine life dispersed throughout the seas, by devising extremely efficient detection and straining systems or artificial methods to cause fish to aggregate where they can be easily caught. Below are listed some likely means of improving harvesting efficiency. Determination of watermass boundaries and surface temperature by infra-red ray procedures. Single-wavelength light beams might facilitate visual fish detection down to depths of 100-200 m, or even deeper. There is scope for refinements in sonar equipment for detecting the direction and speed of fishes by use of doppler sonar, and in high-resolution short-ranged equipment for identification of targets by studying three-dimensional patterns of fish school shapes characteristic of species. It might be possible to develop recording spectrophotometers for tracking organic odours in the sea and thus identify fish schools. This may lead to use of artificial odours to force or guide fish along a given path. Introducing water soluble chemicals into air-bubble curtain might enhance its effectiveness as a fish barrier. Reproducing sounds of prey or predator might be used to attract or herd fish. Electrical fields may be used in conjunction with light, sound or chemical stimuli to aggregate and lead fish. Retrievable floats with built-in detection systems could automatically signal to catcher vessels the presence of fish. A network of unmanned buoys will detect fish and transmit data through satellitic telemetering to a shore-based "hydro-central" for computer analysis and transmission of data summaries by facsimile technique to fishing centres. Motorised units could replace otter boards and even lead to remote-controlled self-propelled trawls. Manned underwater stations for research and harvesting are entirely conceivable. The environment may be improved by fertilising lagoons and by installing nuclear reactors at the sea bottom to create thermal upwelling. Plastics and lightweight metals will be increasingly used in vessels and gear. Irradiation and other innovations in preserving seafood may affect the pattern of fishing operations.

by

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Perspectives de developpement dans la recolte d'animaux marins

Résumé

Pour utiliser pleinement les ressources de protéines des océans, il faut trouver de meilleures méthodes pour récolter la grande diversité d'animaux marins dispersés dans les mers, par exemple, des systèmes efficaces de détection et de filtrage ou des procédés artificiels obligeant les poissions à se rassembler dans des lieux oú il serait facile de les trier. Quelques uns de ces moyens pourraient être: la détermination des limites de masses d'eau et de la température de surface par des rayons infra-rouges; des faisceaux de lumière à onde unique pouvant faciliter la détection visuelle du poisson jusqu'à des profondeurs au-delà de 100 et 200 m. Il est certainement possible aussi d'apporter des raffinements à l'équipement sonar, pour détecter la direction et la vitesse des poissons par l'emploi du doppler sonar, et aussi dans l'équipement à portée réduite à haute résolution pour l'identification des objectifs par l'étude de modèles tri-dimensionnels caractéristiques des différents bancs de poissons. D'autre part, on pourra peut-être développer des spectrophotomètres enregistreurs pour déceler des odeurs organiques dans la mer et identifier ainsi les bancs de poissons ce qui conduirait à l'utilisation d'odeurs artificielles pour diriger les poissons par une route déterminée. L'introduction dans les rideaux d'air, d'éléments chimiques solubles dans l'eau, pourra peut-être renforcer l'effet de barrière de ceuxci. La reproduction des sons émis par les proies et les prédateurs pourra être utilisée en conjonction avec la lumière, le son ou des stimuli chimiques pour guider les poissons. Des flotteurs récupérables contenant des systèmes de détection pourraient signaler automatiquement la présence de poisson aux bateaux de pêche. Un réseau de telles bouées pourrait détecter le poisson et transmettre l'information par télémétrage satellitique à l'"hydro-centre" installé à terre pour analyse par des calculateurs électroniques et transmission de l'information aux centres de pêche. Des unités motorisées pourront replacer les panneaux de chalut et même mener au chalut autopropulsé commandé à distance. Il est à présent possible de concevoir, pour la récolte des mers, des stations sous-marines avec équipage. L'environnement même pourra être amélioré par la fertilisation des lagunes ou par l'installation de réacteurs nucléaires au fond de la mer pour créer des courants thermiques, verticaux. Les métaux légers et les plastics seront davantage utilisés dans la construction des bateaux et des engins de pêche. L'irradiation et autres innovations dans la préservation des produits de mer pourront affecter les méthodes actuelles de pêche.

Evolucion futura de la cosecha de peces marinos

Extracto

Para aprovechar plenamente los recursos de proteínas que existen en los océanos, el hombre tiene que idear métodos mejorados para recoger la gran cantidad y variedad de vidas marinas desperdigadas por las aguas, que pueden consistir en sistemas eficaces de localización y filtrado o dispositivos que les obliguen a congregarse donde pueden capturarse fácilmente. Entre los procedimientos que probablemente mejorarían el rendimiento de las capturas están los siguientes: determinación de los límites de las masas de agua y de las temperaturas de la superficie con rayos infrarrojos; haces de luz de una sola longitud de onda podrían facilitar la localización visual de los peces hasta profundidades de 100 a 200 metros y aún mayores; son factibles de afinamiento los aparatos sónar para determinar la dirección y velocidad de los peces mediante el uso del doppler y los de poco alcance pero mucha resolución para identificar objetos estudiando patrones de tres dimensiones

de formas de cardúmenes características de las especies; debería ser posible fabricar espectrofotómetros registradores para encontrar olores orgánicos en el mar e identificar mediante ellos los cardúmenes. Esto puede llevar al empleo de olores artificiales para hacer que los peces se dirijan por una dirección determinada; el empleo de compuestos químicos solubles en agua en las cortinas de burbujas de aire podría reforzar su eficacia como un obstáculo al paso de los peces. La reproducción de los sonidos emitidos por los predadores o sus presas podría emplearse para atraer o congregar peces; los campos eléctricos podrían emplearse en combinación con estímulos luminosos, sonoros o químicos para congregar y dirigir peces; flotadores recuperables en los que se hubieran instalado aparatos localizadores podrían señalar automáticamente a los pesqueros la presencia de peces; una red de boyas podría localizar los peces y a través de telémetros satélites transmitir datos a estaciones costeras donde se analizarían con máquinas calculadoras y desde las que se transmitirían resúmenes de los datos a los centros de pesca; grupos motorizados podrían sustituir las puertas de los artes e incluso permitir la construcción de artes de arrastre autopropulsados y con telemandos; es perfectamente factible la construcción de estaciones submarinas cuya tripulación humana haría investigaciones y capturas de peces; el ambiente puede mejorarse fertilizando las lagunas e instalando en el fondo del mar reactores nucleares que crearan afloramientos térmicos; los materiales plásticos y los metales ligeros se usarán cada vez con más frecuencia en barcos y material de pesca; la irradiación y otras innovaciones en la preservación de alimentos de origen marino pueden influir en la modalidad de las actividades pesqueras.

1. INTRODUCTION

THE most striking progress in man's efforts to harvest proteins from the oceans has occurred since the termination of World War II. Rapid strides made in development of electronics and acoustical devices have given fishermen better navigational and fish detectional methods. These systems have gone far towards providing the precision navigation needed. Radar increased the capability of inshore navigation and allowed greater safety for around-the-clock fishing operations. Adoption of acoustical devices and sonar for fisheries has yielded a wide array of echo sounders, as well as "fish finders" which are gradually coming into general use.

Interest in a more scientific approach to fish harvest has been demonstrated by the large number of countries which have initiated research into the investigational area now called gear research. Most major fishing nations of the world are now active and some important advances have occurred in recent years. Synthetics have been adapted for twine and net construction and have had a tremendous impact. In mechanics the power block for hauling large nets from the sea has provided fishermen with a more effective method of handling nets. Electro-fishing and mechanisation of the "kilka" fisheries in the Caspian Sea by lights and pumps, indicate that progress is being made. Progress in utilisation of ocean resources, however, is in an embryonic state as compared with ideas which have swept manufacture and agriculture.

Our purpose here is to explore the engineering technologies of the industrial, military and space fields as to their application and use for improving existing or developing new concepts for harvesting marine life. We have limited our considerations to the next three decades. The rapidity of scientific development and the fruits of discovery will, even within this time period, probably outdistance the imagination. In this vein we must admit that science fiction has perhaps already anticipated the greater part of our text.

2. DETECTION AND LOCATION

The location or detection of biological populations can be carried out from above the water or in the water. Much military research has been directed to search and recognition of underwater targets. In specific application military engineering need is diametrically opposed to the fishery need. Whereas great effort has been expended to reduce background "noise" and "clutter" from military devices, the interest to the fisherman is often the source of the clutter and noise. The development problem is the reduction of noise and clutter into its physical and biological components and the amplification of the latter.

2·1 Aerial surveys

The state of the air-sea interface as well as its physical nature limit the utility of the aerial surveys, particularly as to depth. Objects which break surface can be located through high resolution radar. But often the "target" is ephemeral such as the leaping of fish or the surfacing of a whale. These features make target identification extremely difficult even under ideal sea conditions. When the water surface is rough, background scatter is such to make most radar techniques ineffectual for location of fish populations.

2·2 Infra-red detection

Determination of water mass boundaries and surface temperature by infra-red procedures has been conducted on an exploratory basis. Tidal streams can be located with accuracy and temperatures of the surface layer measured. It is not known whether turbulence caused by fish schools swimming near the surface can be detected by infra-red techniques. With suitable sensitivities, theoretically, this anomaly would provide a means of detecting and plotting movements of surface schooling fishes.

2·3 Light

Penetration of light through the air-water interface is slight, except in the blue-green region of the electromagnetic spectrum. Laser[1] (light amplification by the stimulated emission of radiation) offers a means of determination whether a "window" exists in this spectral region. Heretofore studies of electro-magnetic propagation through the air-water interface have been hampered by the lack of pure single wavelength sources. Laser techniques provide the narrow band widths necessary for such a study. If such a "window" exists, some theoretical studies imply that the use of Laser beams would allow reconnaissance of the sea surface to depths of 100 to 200 m, while others forecast much greater ranges. Aerial survey techniques from manned or unmanned vehicles would permit the plotting of aquatic resources in both space and time at much lower cost than is possible today.

[1] A device which produces light as a pure coherent wave in a highly columnated pencil-like beam.

2·4 Underwater detection systems

Subsurface methods of detecting biological resources fall into two general categories: sound techniques and non-sound methods (the latter being facetiously referred to as "unsound" by non-acoustic workers). Both methods can be employed in the active or passive sense. The technological development of sonar has apparently reached an asymptote and it appears unlikely that any major breakthrough will permit detection of biological populations at ranges of greater than 15 nautical miles. Pulse coding and doppler techniques allow some refinements; for example, movement of fishes can be detected both as to direction and speed through the use of doppler sonar. Range of reception (passive) of noises produced by animals is dependent upon the frequency of the production and will probably result in a range limit of the aforementioned magnitude. The only major development likely in sonic fields is for high-resolution short-ranged equipment which will allow identification of targets with relative ease once the population is detected.

Implied along with fish detection is the all important item of identification. The range at which this is possible is considerably smaller than the range of detection. Biological and physical data on the patterns (in three dimensions) of fish school shapes should greatly facilitate remote identification. Just as the field ornithologist can recognise, within a given number of types, the species of bird by the precise manner in which it flies, so fish schools also exemplify patterns in swimming and schooling. In the few instances where school pattern has been studied in sufficient detail, evidence for distinguishing species is promising. Remote techniques of identifying patterns are within the limits of present-day technology. An unmanned active sonar interrogator (high speed submersible or fixed buoy) could compare the pattern of a passing fish school with an "electronic library" of likely species types stored in its memory. Identification of sound producing fishes by the nature of sound characteristics is likewise feasible.

Non-sound methods of location and identification of biological resources are still largely speculative. A possible visual means of searching surface waters has been referred to—Laser. There is biological evidence for believing that fish can detect extremely small quantities of substances in their environment. Much more research is required but, if the basis for these olfactory sensory patterns can be detected, it would be technically possible to develop recording gaseous spectrophotometers for tracking organic odours in the sea. With the accrual of information on fish odour, it would be possible to identify fish schools by spectrophotometric means. An obvious ramification would be the dispersal of a distasteful odour to force or guide fish along a given path.

2·5 Artificial logs

A possible scheme for bringing about aggregations of some of the larger pelagic species, such as tuna, would be the use of artificial log stations (Fig. 1). It is well known that schools of tuna are often found associated with logs or other floating debris.

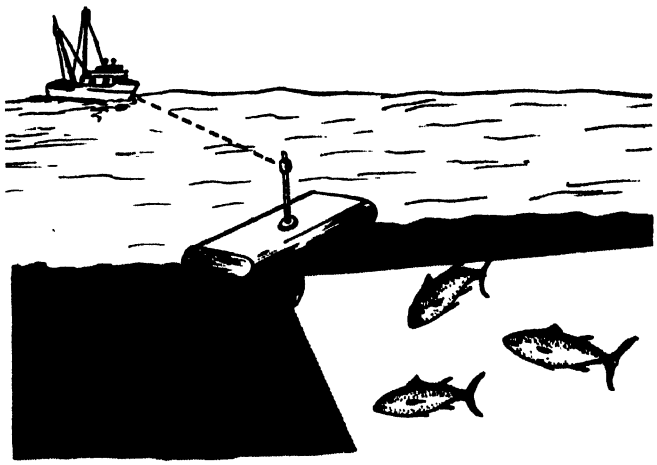

Fig. 1. An artificial log both attracts and detects schools of pelagic fish and relays to a catcher vessel information on concentration of fish in vicinity of the log.

The artificial log could have a built-in detection system, either active or passive, which automatically would signal catcher vessels when concentrations of fish were near. The detection and communication unit would be capable of indicating not only the presence but also the size of fish schools. By using a number of such logs the opportunity of locating and capturing tuna schools would be increased. The logs, constructed of lightweight durable plastics, would be easily retrievable by the catcher vessel.

3. HARVEST

Most existing world fisheries rely on environmental systems or inherent biological characteristics of fish to provide concentrations or aggregations necessary for fishing. Thus the majority of fisheries are in restricted oceanographic areas where relatively high productivity has provided the environment suitable for sustaining concentrations of fishes. If man is to realise the full protein harvest from the seas, he must devise methods to utilise the great diversity of forms throughout a large geographic segment of the oceans. Many of the latent resources may not form natural aggregations but may be widely dispersed throughout the seas. Maximising the harvest of the oceans thus confronts man with several alternatives: (a) he must devise extremely efficient straining systems, or (b) he must devise artificial methods which will cause fish to aggregate where they can be easily captured.

3·1 Modification of conventional gears

Within the realm of contemporary fishing gear, more effective harvest of mid-depth forms has been progressing by developments in midwater trawling techniques. Current investigations into improved electrical conducting cables could provide fishermen with the means of monitoring the rates of fish capture in either bottom or midwater trawls, and through shocking systems to prevent fish escaping from nets after once entered.

Within the realm of existing technology, it is feasible to consider motorised units to replace otter boards and other net-spreading devices which depend upon hydrodynamic characteristics for operation (Fig. 2). The powered unit to replace the conventional otter boards could control the depth of the midwater trawl and its gape as well as the attitude of the net.

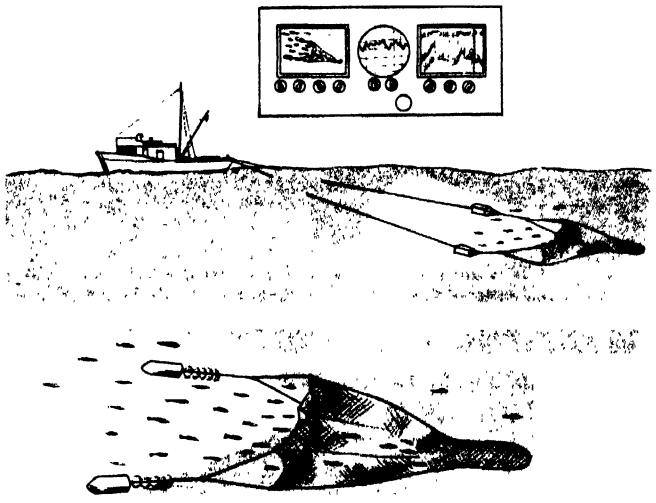

Fig. 2. Conventional otter trawlboards have been replaced with powered spreading devices. Cables with electric conductors relay information to ship's bridge concerning the concentrations of fish in front of the trawl, the behaviour of the gear on the bottom, and quantities of fish entering the mouth of the net. A remotely-controlled midwater trawl is deployed from the catcher vessel.

Research currently devoted to guiding unmanned submersibles may in future allow development of remote-controlled trawls. Such trawls could be directed from aboard ship and would be of particular value in exploiting herrings, sardines and other densely schooling fish. The motorised trawl perhaps would provide the straining capability which may one day be needed to harvest the lower trophic forms (zooplankton, etc.).

A development likely to occur soon is remote controlled motorised submersibles which could be employed for aiding in setting and closing of large purse seines or gillnets. Military needs are likely to control the rate at which manned underwater vehicles will be developed. This is primarily because of the great expense in developing such a chamber with suitable safety factors. At least one firm has stated, however, that once the design was frozen, the construction could be completed in about a year. Their use would accelerate and parallel development of unmanned vehicles.

3·2 Air bubbles and chemical curtains

A barrier to fish movement which shows some promise is the bubble curtain. This technique involves the pumping of air through a hose laid on the sea bottom and the resulting bubbles form a barrier to the movement of some species. The introduction of a water soluble chemical into the bubble curtain has been proposed. These chemicals would serve to enhance the effectiveness of the barrier.

3·3 Odours, light and sound

Perhaps some of the most interesting by-product developments of space and military research which may have application to fish capture are those previously mentioned as techniques for fish detection (light and odours). The possibility that fish detect their prey or predators through olfactory stimuli and thus track down prey or avoid predators, presents man with the opportunity of duplicating the odours which either attract or repel fish. Possible artificial aggregation can be achieved by introducing a scent or trail which duplicates that of prey. Fishing vessels could then proceed to areas where the artificial odours had concentrated schools of tuna, herring mackerels, or other species. Likewise, odours may be used to repel and thus direct certain fish to areas where they may be captured. Aircraft or underwater vehicles could lay out systematic patterns (Fig. 3) of odour-producing chemicals for attracting particular species.

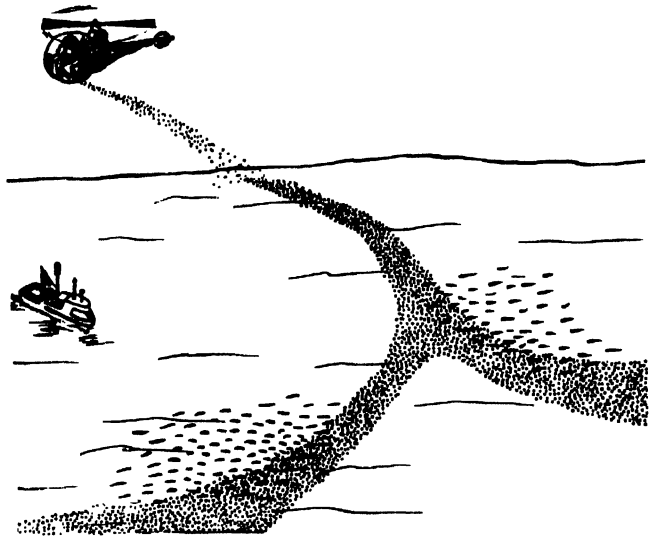

Fig. 3. Helicopter deploys chemicals which concentrate fish. The catcher vessel will subsequently proceed to the area of concentration and harvest schools of pelagic fish.

A similar approach might either attract or herd fish by reproducing the sounds of prey or predators. The use of electricity or electrotaxic methods for capturing fish is definitely feasible for emptying nets or for bringing fish aboard a catcher vessel. However, because of power losses imposed by physical limitations, we do not believe these methods will attract fish from any great distances. Use of electrical fields, however, in conjunction with light, sound, or chemical stimuli to help aggregate and lead fish is likely. All of these means are dependent on determining the basic biological and behaviour characteristics of various species to these various stimuli.

3·4 Underwater harvest

Not to be overshadowed by advances in fishery is the development of techniques for studying the environment. Our French colleagues have already shown the real possibility of establishing research colonies at depths for extended periods. It is entirely conceivable that, in the

distant future, some types of harvest and production could be accomplished at fixed locations under the sea and the end produce moved by freight submarines to consumer ports.

4. MODIFICATION OF THE ENVIRONMENT

When meteorological and oceanographic models have been tested and integrated, it is probable that the environment can be modified, at least on a limited scale. Certainly weather conditions will be changeable, and even a small change projected over several months can have an influence on the aquatic environments. Small term shifts and currents could be used to direct movement of fishes to more desirable or accessible locations. Calculations have been performed which suggest the installation of a nuclear reactor (Fig. 4) at the bottom of the sea could bring about thermal upwelling on a limited basis. Where nutrient production is critical, for example in a nursery ground or area, such a scheme might find utility. On a broader range the possibilities are endless but it is hoped that such manipulations of the future will take into consideration the fact that, while it might be possible to modify the environment, we should assess the change critically as the same techniques might not readily return the environment to its near initial state.

The future of fish culture looks brighter. Fertilising and farming the seas is not remote when considered in terms of chemical fertilisation of restricted access areas so as to provide nutrients for essential food items. Studies of such artificial enrichment of lagoons and other relatively confined bodies of water capable of handling large numbers of fishes have indicated this to be commercially feasible.

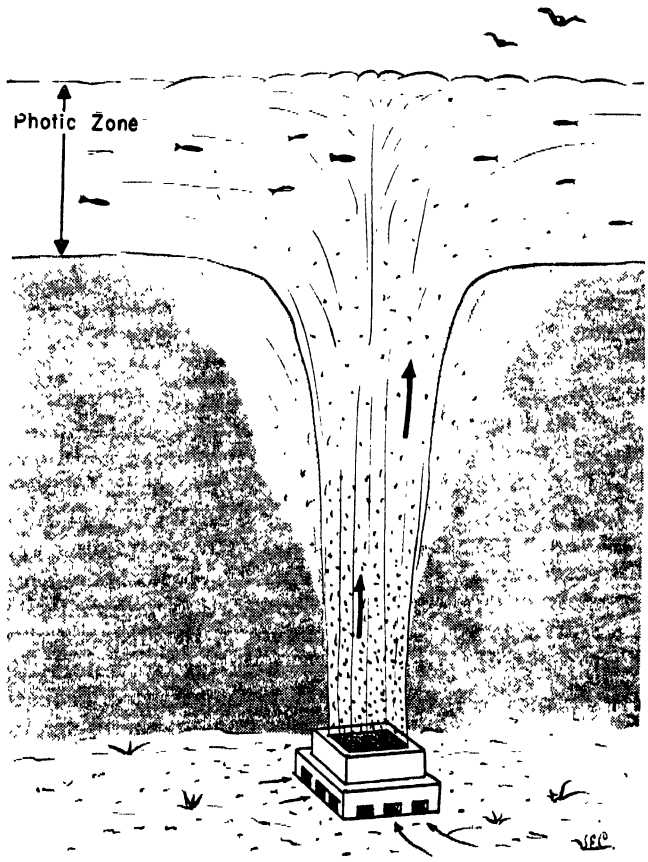

Fig. 4. Nuclear reactor on ocean floor provides heat necessary to bring about upwelling process. The deeper waters (rich in nutrients) provide continued high productivity when reaching the upper photic zone.

5. COMMUNICATIONS

Weather data now being gathered from satellites (and soon to be obtained from a net of meteorological buoys established on the ocean surface) will allow the development of more accurate and longer range meteorological predictions. The forecasting of the events which bring about El Nino conditions and prolonged rough-sea states will allow better deployment of fishing fleets up to three months in advance. Surface communication and navigation through satellites could provide for the rapid transmission of fishery intelligence on an automatic basis. These same developments will allow the preparation of more accurate charts. Associated navigational schemes (available today for limited areas) will allow fishing fleets to operate in waters considered inaccessible by contemporary standards. Fishable grounds will be pinpointed with accuracy and autopilot vessel operation will allow large fishing vessels to return to trawlable grounds within rough territory with repetitive accuracy in all types of weather.

However, there are problems "of space" in this area. Available transmission frequencies are rapidly being exhausted for other scientific and commercial purposes. It behoves the authorities of all nations to consider suitable transmission frequencies for the fishing industry.

6. MATERIALS

The demands which space vehicles have made on industries for development of lightweight, high-strength metals will certainly provide side-benefits to the fishing industry of the future. Pure and alloyed light metals such as aluminum, titanium and beryllium, may well offer construction materials for vessels, vessel machinery and cables, which should decrease the deadload and consequently increase the payload of fishing craft. Aluminum in fishing craft is already widely accepted and titanium is currently commercially available. Such materials are not always as reliable as their precursors; but only use will provide such data. Perhaps the most challenging of the lightweight metals is beryllium. This material has a high weight to strength ratio, with a density of only 1·8 g/cm^3. This may be compared with iron which has a density of 7 g/cm^3, titanium with 4·5 g/cm^3, and aluminum which has a density of 2·7 g/cm^3. Use of beryllium is currently limited because of high cost and difficulties in fabrication. Small particles of this element (chips, etc.) have proven toxic to industrial workers. It seems likely that these problems will be resolved and satisfactory systems can be developed for processing and working these materials.

Engineering technology has already demonstrated that use of fine filament wires greatly increases the

strength of a material per cross-sectional area. One can therefore anticipate the development of a cable composed of fine filament beryllium which would have extremely low weight and high strength. Such a development would reduce the required diameter of cable needed and greatly reduce the weight of comparable cable used in deep-sea trawling.

In plastics, float materials are already available which will withstand great depths and provide considerable buoyancy. If materials as mentioned should be available commercially in the next several years, they would overcome the problems involved in deep-sea operation. The use of both plastics and lightweight metals in vessel construction seems a certainty.

7. PROPULSION

We look with some anticipation to the development of smaller and lighter weight propulsion units. Gas turbines, which are currently being tested aboard smaller naval craft, could find wide use in fishing industries when fuel consumption and reliability problems are solved. Although there is considerable debate as to when small atomic units might be available for fishing craft, there seems little doubt that technically it would be feasible to employ such units in larger distant-water factory or support vessels. Within the next several decades, smaller atomic units could well be available for smaller fishing craft. It is even conceivable that other sources of energy might be employed which would allow reduction in current space devoted to engine-rooms while increasing reliability.

8. PROCESSING OF FISHERY PRODUCTS

Revolutionary innovations in preserving and processing seafood products undoubtedly will occur within the next few decades. Two of the most exciting preservation developments expected to occur are irradiation-pasteurisation and freeze-drying.

8·1 Irradiation and pasteurisation

The normal storage life of iced fish and shellfish is now from one to two weeks. By pasteurising seafood by irradiation prior to placing it in ice, the storage life probably can be extended to a month or longer. Within 30 years irradiation-pasteurisation should be in general use for those products which can be brought to central irradiation plants. By then experimental mobile irradiators also should be available. Eventual adaptation of mobile irradiators for use aboard motherships or even larger catcher vessels would reduce (but not replace) dependence upon freezing catches at sea when frequenting grounds distant from port. Irradiation-pasteurisation also will make seafoods more available to people living in inland areas where cold storage facilities are lacking.

8·2 Freeze-drying

Freeze-dried seafoods should be commonplace within the next 30 years. This process, which removes water from frozen foods at relatively low temperatures, provides a superior dried product. By adding water to the dried product it is restored to an essentially fresh state in less than one minute. Species processed by this method will necessarily be those with a relatively low oil content. Shellfish, such as shrimp and oysters, would be particularly suited to freeze-drying. For some species, such as shrimp, freeze-drying may in part replace canning. Advantages of freeze-dried over canned products include greater resemblance to the fresh items, especially with regard to texture, and greater convenience for use. Once opened, canned goods have to be used within a fairly short time. By contrast, water could be added to all or any portion of freeze-dried seafood upon removal from its container. A disadvantage of freeze-dried seafood would be its somewhat shorter storage life than canned products.

8·3 Fish protein concentrates

Hope for more than one-half of the world's population who suffer from an inadequate diet is offered by current research to develop a satisfactory fish protein concentrate (fish flour). Within the next few years technical processing problems should be solved which will result in the large-scale manufacture of fish protein concentrates suitable for world-wide incorporation into human diets. Many species of fish now discarded at sea for lack of markets could be converted into fish protein concentrate. This would, of course, provide a tremendous stimulus to the fishing industry.

9. FISHING IN THE FUTURE

A fictional picture of fishing in the future might run along the following lines:

A net of unmanned buoys has been established for several years in the sea and the patterns of occurrence and distribution of natural resources have been determined and plotted (Fig. 5). The buoys are interrogated at regular intervals through satellite telemetering and from their surface transmitters by pulse-coded sonic means to instrument heads at various depths in the sea. Transmission redundancy is reduced to a minimum as only points of parameter change are telemetered. As the data come in to "hydro-central" (Fig. 6), computers reduce the mass of informational bits to contoured plots of biological oceanographic and meteorological parameters. By facsimile techniques, these data summaries are transmitted to the research laboratories and fishing centres of the world. When a biological parameter anomaly occurs, the nearest buoy would automatically be instructed to assess the nature of the instance with high-resolution sonar and auto-spectrophotometric methods. These data would be transmitted back to hydro-central for computer and human interpretation. The movements of the identified resources would be plotted.

In some instances it might be necessary to verify the nature of the resource or an anomaly by an on-the-spot check using aircraft perhaps equipped with Laserscopes or hydrofoil research craft equipped with high-speed self-propelled submersible television vehicles.

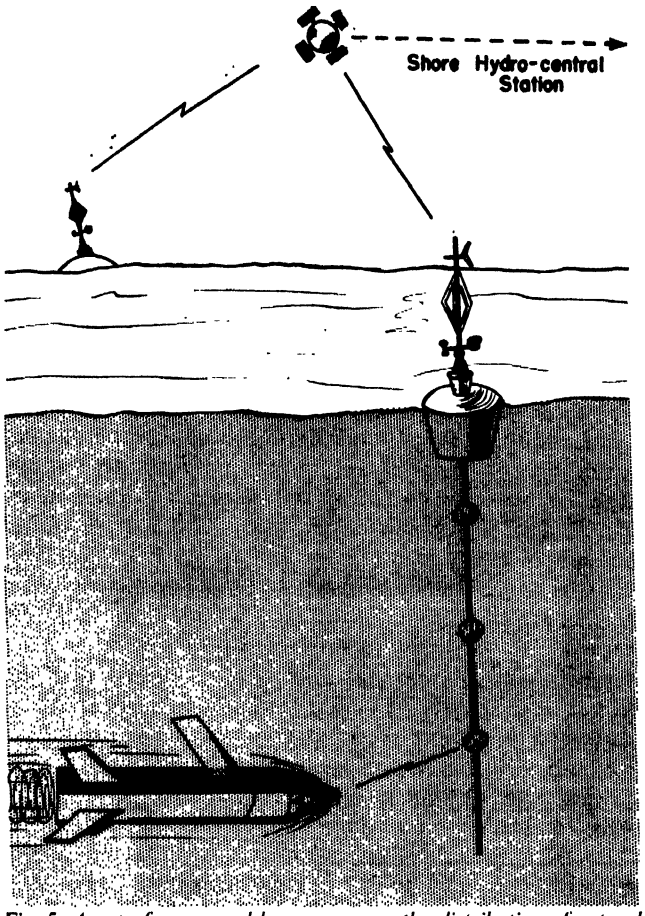

Fig. 5. A net of unmanned buoys assesses the distribution of natural resources in the sea. Information collected concerning water properties, which are important factors in fish distribution, is relayed via a satellite to a shore station ("hydro-central").

Depending on the species, the main fishing fleet could be deployed into the path of the fish, or conversely, suitable deterrents could be placed in the sea to guide the fish to the catcher. Aircraft could disperse the necessary chemical pellets to olfactorily guide the fish, or remote-controlled underwater vehicles would produce the necessary electrical -sonic or bubble barrier to perform the same function. Depending on the depth of harvest, catches would be performed by catcher boats assigned to permanently anchored factory ships or by automated underwater vehicles operated from ship or shore stations.

Surveillance of the main plotting board in hydro-central would allow detection of weather conditions and precursors of El Nino type shifts in advance. Similarly, areas of high or low basic nutrient production could be watched and, with broad environmental limits, spawning populations deflected accordingly.

Although this picture of the future may appear revolutionary to the point of distastefulness, one can always find refuge in the fact that the conservative nature of fishermen will tend to stabilise the road to change and progress. That such changes will eventually occur seems undebatable. There appears to be little difference whether the developments are sponsored by individual firms and companies or as part of the national economy. The increasing population growth is already far outdistancing our protein production. Clearly, the social and economic factors must parallel technological developments; otherwise, local over-fishing, market development, over-regulation and duplication of effort will bring about the destruction of the very goal being sought.

continued on page 590

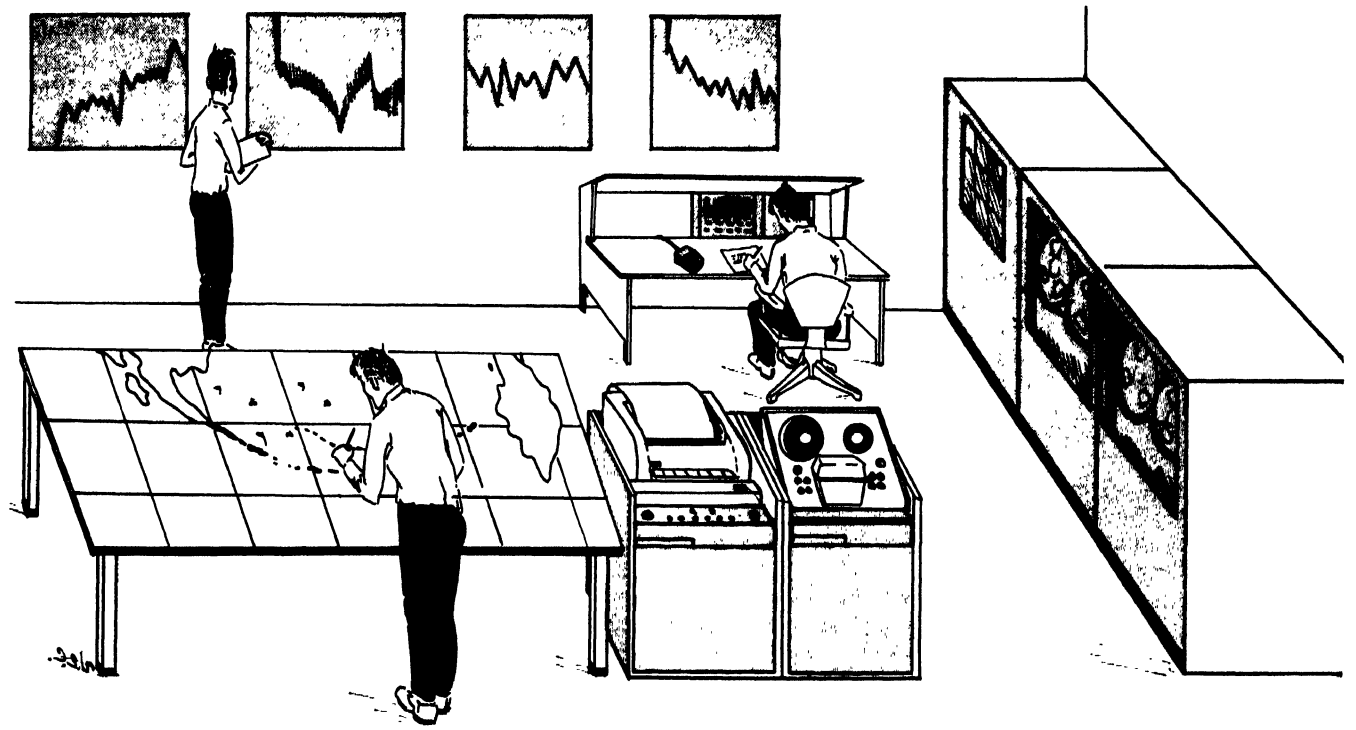

Fig. 6. A data collection centre ("hydro-central") analyses incoming information and quickly transmits data to research laboratories and fishing craft concerning weather, water properties, and indicated distribution patterns of resources.

Automatic Data Processing and Computer use in Fisheries

Abstract
This paper indicates some of the possible applications of the high speed computer and associated elements of automatic data processing (ADP) to the fishing industry. The author feels that the fishing industry cannot afford to overlook the advantages and possibilities of the incorporation of effective ADP techniques into its operations any more than they could disregard the advantages of modern engines, mechanical refrigeration, electronic instruments and other modern assistance both afloat and ashore.

Résumé
La communication indique quelques applications possibles des machines à calculer électronique et des éléments associés de traitement automatique de données (ADP), a l'industrie des pêches. L'auteur pense que cette industrie ne peut ignorer les avantages et possibilités de l'utilisation de techniques ADP, pas plus qu'elle ne peut ignorer les avantages des machines modernes de réfrigération mécanique, des instruments électroniques et d'autres aides modernes a terre ou en mer.

Extracto
Indica la ponencia las posibles aplicaciones de las máquinas calculadoras, de gran velocidad y elementos asociados de preparación automatica de datos, a la industria pesquera. El autor cree que la industria pesquera no puede hacer caso omiso de las ventajas y posibilidades del empleo de técnicas eficaces de preparación automática de datos en us actividades, como tampoco podría hacerlo de las ventagas de los motores, refrigeración mecánica, aparatos electronicos y otros auxiliares modernos en tierra y a bordo.

by
Benjamin F. Leeper

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WHEN a few years ago, the first sequence-controlled computer was built, it was regarded more as a curiosity than as a practical tool. And when the first electronic digital computer was installed in the United States Bureau of the Census, the estimated potential market for the entire United States of America was set at 17 machines; yet, in June 1962, the number of computers in the United States was 9,500 and growing rapidly.

Automatic data processing cannot supply information, but can only process it.

Automatic data processing involves the use of simpler equipment for handling bulk data than computers, but it is to the computer that we must turn for solution to complex problems and to really obtain full value from accumulated records.

The number of tasks to which a computer could be put in fishery research and practice is infinite, but it must be remembered that the basic requirement is reliable data which can be fed into the machine. One very simple example, however, may be given of possible use. In any endeavour, the man who knows what his chances are of winning is the man who will most likely succeed. If adequate records of voyages and catches together with all seasonal and weather data could be fed into a computer, it would undoubtedly increase the chances of a skipper securing good catches.

Whereas by hand one could only work with small samples and a limited number of variables (species, areas, seasons), with a computer such factors as bottom type, dragging with or against the current, sea state, net size and type, and others can be added to define the limits more concisely. Still the operation will be a relatively simple one for a computer.

Basic statistics have become an important part of the computer load in most installations, and regression, correlation, and matrix algebra programmes are important parts of the library of routines.

Fortunately many of the more useful of these methods are fairly standard and are available for most computers.

Any researcher would shudder at having great masses of material flooded to him for evacuation but scanners have been developed that can read several types of continuous charts and reduce the readings to digital values at predetermined increments. It is not impossible that a computer might be programmed to abstract

continued from page 589

If the fishing industry is to provide the raw materials required for large-scale production of ocean resources, rapid progress will be required in harvest and processing methods. Advances in fishery harvest are not limited only to existing technology but by major gaps in basic biology. Much more effort must be devoted to gathering fundamental knowledge on fish of all species before improvement can be had in harvesting marine resources.

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University of Washington
U.S. Bureau of Commercial Fisheries
U.S. Navy Electronics Laboratory
U.S. Weather Bureau
Van Camp Sea Food Company

individual voyage records with a minimum of hand operation.

There can be little doubt that as our students of basic science become familiar with the ability to make rapid determinations between the effects of large numbers of variables and to filter out promising clues without being faced with months and years of hand labour to have their ideas validated, or discarded, recognisable factors of cause and effect will provide inestimable benefits, and it is doubtful that there will be a more fruitful media for these studies than is to be found in the sea.

Discussion on Advance in Science and the Future

Mr. D. L. Alverson (U.S.A.) Rapporteur: Mr. Leeper's paper reviews some of the general applications of automatic data processing to fisheries and provides information concerning assessment and preparation of information to be presented to an automatic data processing system. In essence, ADP is the application of rather simple equipment to handling and recording bulk data which can be subsequently summarised and complicated problems resolved by computer analysis. Automatic data processing has, of course, been applied to a variety of purposes in both the scientific and business fields.

Mr. Leeper notes, in introducing one of science's brightest protégés (ADP) to one of the world's oldest industries, that the most brilliant and beneficial accomplishments must come from those concerned with the harvesting and processing of ocean resources. It is noted that ADP cannot supply information, but coupled with technical knowledge and mechanisation, can improve efficiency. Mr. Leeper refers here to efficiency of processing and evaluating data concerned with fisheries science and/or the business end of fisheries. The author points out that in fisheries operations both afloat and ashore we may well borrow from the experiences of other industries in adopting ADP for the processing and recording of data. It is suggested that ADP may be suitably adopted for basic research activities, and that computers have been developed that can read several types of continuous charts and reduce them to digital values and predetermined increments. Thus, the computers may be programmed to extract individual voyage records with a minimum of hand operations.

A case for increasing the fishing efficiency is provided by proposing ADP, as a method for programming statistical opportunity of probability of catch. His analogy is this: "In any endeavour, the man who knows what his chances are of winning is the man who will most likely succeed. Would it not be helpful if we could say, go to a specified area in a specified season and obtain from (for instance) 1,500 to 2,000 tons of cod in a certain amount of fishing time? By accumulating careful records over the year, converting them to computer language, and programming a very simple statistical treatment, we can determine with reasonable surety the most probable catch to be derived from an area." A variety of other uses for automatic data processing are proposed, including statistical analysis of scientific data, forecasting the distribution and abundance of fish patterns, market analysis, routine business operations, and information retrieval. Can we afford to overlook the advantages and possibilities of effective ADP techniques any more than we might disregard the advantages of diesel engines, radar, sonar and other modern aids? At the same time each potential user must examine and weigh carefully the advantages of ADP before embarking on it.

Concerning the paper on the future aspect by himself and Mr. Wilimovsky, this, although some might have considered it fanciful and imaginative, was meant to be constructive in its opening-up prospects of securing information through the very advanced fields of space technology and military research. He had had the opportunity of visiting all the organisations mentioned at the back of this paper, and talking to prominent people in all branches of the industry. A lot of thought by many important scientists had gone into the paper and all the points mentioned were definitely feasible and possible of attainment provided the finance for achieving them was provided. As in industry, we cannot afford to ignore the possibilities open to us by the avenues mentioned. Having regard to the population explosion and the future world food need we will be required to move ahead and develop new techniques for securing greater resources from the ocean. We will have to discover means of utilising stocks and resources that are not now being utilised and to do so we must evolve new techniques to achieve our purpose. The purpose of the paper was to start people thinking along those lines.

Mr. D. J. Doust (U.K.): As a naval architect I would like to speak about some of the applications of computers in our field which is allied to your own. With the increasing numbers of second generation computers able to tackle large-scale analytical studies many previously insoluble problems in fisheries research are now within sight of solution. For example, in fishing vessel design we are now able to determine the optimum parameters of the hull form to specified design conditions using high-speed digital electronic computers to evaluate the performance. The results of all previous tank tests conducted under laboratory trial conditions are analysed using multilinear regression techniques which are particularly suitable to some types of computer. (Incidentally some forms of computer were very much *not* suited to this type of research study.) The Fishing Boat section of FAO was currently engaged on large-scale analysis of this type which should prove of great value to owners and builders of smaller fishing vessels. The fabrication of the ships' hull and of internal structures is clearly possible for defining the lines of the vessel in mathematical terms and using computer controlled machines to cut the various plates and components which go to make up the final hull form. These applications are, of course, particularly valuable in the production of fishing vessels which are so often built in considerable numbers to the same design permitting the cost of computer technique per vessel to be considerably reduced. Many types of management problem in the fishing industry and in many others had already been solved using the mathematical aids available in operational research most of which rely on a mechanical solution using the aid of the computer. There is every indication that techniques of this sort will apply in an ever-increasing role in the fishing industry since it is evident that the fast-moving developments of the day had in some cases overtaken the previous lack of experience to such an extent that decision taking has been a somewhat risky business. In those circumstances, decisions are, in fact, deferred until the issues become clearer. This is where, I think, we have a big opportunity of using the computer to help us by studying our past background of experience to foretell the future. Typical examples of the need for decision taking are provided by some of the subjects such

as the most economic size of fishing vessel for particular fishing areas, whether to adopt a large mothership supplied by a number of small catchers or to increase the radius of action and size of the distant-water trawler fleet, to select the most profitable speed of operation of a fully refrigerated trawler and many other associated economic and technical problems, can all be tackled by these techniques. In the fields of the gear technologist with the hydrodynamic research now being undertaken, both model and full-scale tests, so well illustrated in Mr. Crewe's paper where accurate records are becoming available, lend themselves to better methods of performance. A good example here is provided by the orientation of the trawl boards and net surfaces when the vessel is engaged in trawling operations by formulating the general equation of motion of the various components, hydrodynamic and gravity forces in the overall term, and, knowing the external forces acting on the deck which are transmitted back to the towing points of the vessel, it should not be impossible to derive the net configurations for particular towing speeds, warp lengths and mesh sizes under seagoing conditions. In such cases where a particular problem of fishery research can be expressed in equational form and where adequate precision of input data can be supplied, the computer can be used to determine the required solution without difficulty.

Dr. Cole (U.K.): I do not believe it is just sufficient to think about long-range lines of work that might result finally in very substantial improvement in the amount of food we can get from the sea. It is necessary to act and to begin, wherever possible, work of a forward-looking nature. Old-established fishing institutions should be able to employ a few men along these lines. My own special interest is the augmentation of the stocks of fish. In that line we have had three men at work on the artificial production of plaice and we propose to extend this as soon as possible to cover commercially valuable species of fish such as crustaceans and molluscs. That has nothing to do with gear research, but Mr. Alverson has thrown enough ideas into the pool to enable communities that had a substantial number of people engaged in fishery research, to select topics from which they can make a start. Techniques of aggregation are going to be of very great importance in the future. They are important not only in the case of grounds that cannot be commercially fished but also in heavily fished areas because if we can improve the catch per unit effort by concentrating the fish closer together so that they can be swept up at lesser cost we will be doing a very successful job.

I would also like to refer to Dr. von Brandt's paper on the organisation of gear institutes and research as a whole. He has very courageously put his ideas on paper but I am not at all sure that gear research and technology should be organised in separate institutions apart from biologists and so on. I do not like the idea of making a biologist into a hydrodynamist. I much prefer a team of full, qualified specialists. Why can't we have them all working together in some institution and in that way we will make sounder and more rapid progress.

Dr. W. M. Chapman (U.S.A.): I would like to extend some remarks by Dr. Cole and describe some of the things that are going on at the present time which I am sure will have quite a startling effect on the fishing industry in the coming years. I think that perhaps people dealing with fishery research in the ocean are often a little too close to the work they are doing to see how well the general subject is developing. One of the principal objects of fishery research is the production of events in the ocean and, in respect of the resources of the sea, of events of such a nature that the fisherman can take advantage of the products of their work and reduce the cost per ton of production. The basic problem of fishing is to strain the fish out of the water. And in that connection aggregation is a prime factor so that the fisherman can get a big catch in a small amount of time. So one of the problems involved is the aggregation of the fish. Useful work on this is already being done. This is work which enables one to estimate and perhaps predict the aggregative effects of various ocean parameters so that the instrument can take advantage of them. We have several of these factors of ocean conditions upon which some definite progress is being made. One is that of the surface temperatures. This is not, at the moment, of tremendous importance to trawlermen but when the Lowestoft people get their thermograph working on trawl boards and footropes the trawlers will find out that the same thing I am referring to, does affect them as well as the tuna people in the Eastern Pacific. We are now regularly charting the surface temperatures of the Eastern North Pacific and publishing them at intervals quite regularly. This is being done by the Bureau of Commercial Fisheries, Los Angeles. These temperatures are compiled from the records that the merchant ship send in for the weather bureaus. These are all automated, tapped out by machines, and punched onto cards according to a programme. Once every month a bundle of cards is taken down to the computer and in the matter of an hour or two the man is back with the information. One afternoon's work enables us to split not only the surface temperatures for the whole of the North-eastern Pacific (as for the middle of that period) onto an average but also chart the deviations of the isotherms over that period from the same situation a year previously and, in the second place, to relate that to a 15-year mean. This has become of enormous importance to the tuna fishermen of the Eastern Pacific—in particular to the albacore catchers and also of other tropical tuna as well.

In Tokai University in Japan they are doing this on a different basis with respect to the North-west Pacific Ocean and are extending their work in respect of some parameters to cover most of the world's ocean. At any one period of time, they have about 600 tuna fishing vessels scattered over the tropical and sub-tropical oceans, most of whom are in touch with the station at Tokai daily or at least weekly. They relay the measurements of the parameters they are concerned with to those stations and they are correlated in Japan and are relayed out to the ships at five- or ten-day intervals. This relaying is now being done by facsimile television and these facsimile methods have been worked out quite rapidly. A year ago the dispatch did not reach more than 500 miles from Tokai but when one of their big vessels was in San Diego recently she was receiving facsimile reports from Tokyo quite regularly and that is a distance of a few thousand miles. Surface temperatures are also being handled in the North Atlantic by the U.S.A. hydrographic bureau and the same charting is being done now in the Indian Ocean area and the Intergovernmental Oceanographic Commission now has under consideration two things —first the compilation of surface temperature charts on a world-wide basis, keeping in mind that some fishing countries are now interested in all parts of the world ocean so that they would like to know the position over the whole area. There are certain phenomena that repeat themselves and a great deal of use can be made of them. We will find in a period of just a few years a widespread gathering of information from vessels at sea. This will be correlated at short notice by computer assistance and then immediately relayed out to the vessels at sea for their use. This will require a great deal of information to be gathered and some understanding from the fishermen at

sea. At present the information mainly comes from commercial merchant vessels but as they do not cover all areas, the co-operation of the fishermen themselves on their vessels at sea will be required. Fishermen will have to be convinced that it is money in their pockets to co-operate. There are two ways of getting this problem solved in respect of regular collaborative distribution. Once you have the charts of the parameters produced by the computer they can be distributed by the facsimile methods such as Japan is using, but another method may be to shoot one of these charts up to one of the communication satellites at regular time intervals so that it can be received on board vessels on television sets. This is being handled and programmed by people now in an experimental way. It may prove to be quite useful to have such information easily available to men at sea.

On the computer side my company, the Van Camp Organisation which operates in nine countries, sells in 38, harvests 800,000 tons of fish of various kinds, now makes use of computers. We bought one five years ago. Two years later it was too small for our use. We bought another one, a much larger one and more complicated. It was supposed to satisfy our needs for 15 years. But at the present time we are now building a house to contain a bigger one and have hired two more biologists to try and interpret what the computer is doing. The computer technique as applied to the fishing business as a whole is being utilised by our hard-nosed board of directors.

Mr. Alverson, summing up, added the comment that the salmon fishermen in the Pacific north-west were also keenly interested in watching the temperatures data distributed by the Bureau of Commercial Fisheries as well as the tuna men.

A New Fish Trap Used in Philippine Waters

Continued from page 286.

The tables mentioned are given on this and the following page. Table I, because of its size is on the next page.

Table II appears below.

Table III—dealing with the ropes and other accessories is now conveniently summarised thus:

Primary float line (manila rope as are all the ropes), diameter in cm 0.9, length 27.1 m, 70 floats tied at 3.5 cm distances.

Secondary float line, 1.5 cm, 27.10 m, where the lacing line of selvage is hung.

Breastline 1.5 cm, 12,20 m, where the lacing line or width is hung.

Primary leadline 0.9 cm, 22.60 m where the lacing line of cotton selvage is hung.

Secondary leadline 1.5 cm, 22.60 m, lead weights are tied at 35.5 cm distances.

Pursing rope, 1.3 cm, 50.0 m, each end is tied to the end of the primary leadline.

Bridle line, 0.9 cm, 0.50 m, 62 pieces, distributed along primary leadline 45.5 cm apart.

Floats are of soft wood 4 cm in diameter, 7.6 m long, 70 pieces, equally distributed along the primary corkline 30.5 cm apart.

Sinkers, lead, 4 oz., 62 in number, equally distributed along the primary leadline 35.5 cm apart.

Table II. Specification of the seine (sigin)

Parts	Symbols	Materials		Size of meshes stretched	Horizontal	Meshes deep	Strip	Remarks
		Kind	Twine Number					
Bunt	A	cotton twine	12	2.24	312	500	1	Nettings joined mesh to mesh
	B	cotton twine	9	2.54	300	300	1	
Wings	C	cotton	9	2.54	573	800	1	Nettings joined mesh to mesh. Outer edges of bunt and wings are joined to the selvages (4 meshes of the former to every mesh of the latter) and then laced by a 26-thread cotton twine to the hanging line.
	D	"	9	2.54	573	800	1	
S	E	"	36	5.72	7	486	1	
E	F	"	36	5.72	7	407	1	
L	G	"	36	5.72	7	220	1	
V	H	"	36	5.72	7	220	1	

Table I. Specifications of the new hasang moderno operated at Kalibo, Capiz

Parts					Bamboo screens			
Name	Symbols	Length in metres	No. of posts	No. of screens	Size of screens in metres depth x length	Size of splits in metres width x length	Distance between splits in metres	Remarks
	AB1	30	6	12	4.2 x 5	0.02 x 4.2	0.12	Except for A1, two rows of bamboo screens are set on the framework overlapping each other by 10 cm
L	AB2	35	7	14	4.0 x 5	0.02 x 4.0	0.12	
E	AB3	35	7	14	3.8 x 5	0.02 x 3.8	0.12	
A	AB4	35	7	14	3.5 x 5	0.02 x 3.5	0.12	
D	AB5	35	7	14	3.2 x 5	0.02 x 3.2	0.12	
E	AB6	35	7	14	3.2 x 5	0.02 x 3.0	0.12	
P	AB7	35	7	14	3.0 x 5	0.02 x 3.0	0.12	
	Total:	240	28					
W	DC	29	6	12	4.2 x 5	0.013 x 4.2	0.83	Two rows of bamboo screens are set on the framework overlapping each other by 10 cm
	DE	15	3	6	4.5 x 5	0.013 x 4.5	0.83	
I	YZ	29	6	12	4.2 x 5	0.013 x 4.2	0.83	
N	XY	15	3	6	4.5 x 5	0.013 x 4.5	0.83	
	JI	28.50	6	11	4.7 x 5	0.013 x 4.7	0.12	
G	NU	14	3	6	5.4 x 5	0.012 x 5.4	0.42	
S	UV	28.50	6	11	4.7 x 5	0.013 x 4.7	0.12	
	TU	14	3	6	5.4 x 5	0.012 x 5.4	0.42	
	Total:	171	40	70				
Fore-	DF	12.50	4	4	4.5 x 6.25	0.013 x 4.5	0.83	
cham-	FG	30.25	10	10	4.9 x 6.15	0.013 x 4.9	0.83	
ber	YW	12.50	4	4	4.5 x 6.25	0.013 x 4.5	0.83	" "
	WG'	30.25	10	10	4.9 x 6.15	0.013 x 4.9	0.83	
	Total:	85.50	28	28				
Semi-	IK	10	3	4	6 x 5	0.012 x 6	0.42	
cir-	KL	36.50	12	14	6 x 5.30	0.012 x 6	0.42	
cular	LS	4	2	2	6 x 4	0.012 x 6	0.01	" "
enclo-	RQ	4	2	2	6 x 4	0.012 x 6	0.01	
sure	QU	46.50	15	18	6 x 5.30	0.021 x 6	0.42	
	Total:	98	34	440				
Ter-	LM	2.80	2	3	6 x 2.50	0.012 x 6	0.01	
minal	MN	8.50	4	6	6 x 4.30	0.012 x 6	0.01	
pound	NO	3.50	2	3	6 x 3.70	0.012 x 6	0.01	" "
	OP	8.50	4	6	6 x 4.30	0.012 x 6	0.01	
	PQ	2.80	2	3	6 x 2.50	0.012 x 6	0.01	
	Total:	26.1	14	21				
Gates	EB	6.50						
and	BX	6.50						
en-	NG	3.20			A bamboo bridge is constructed above each gate and entrance.			
trances	GT	3.20						
	GG'	4.25						
	RS	0.50						

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